Winnicut Dam Removal DRAFT Feasibility Study

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PREPARED FOR

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EXECUTIVE SUMMARY

The purpose of the Winnicut Dam Removal Feasibility Study (Feasibility Study) is to evaluate options for the restoration of native diadromous and resident fisheries, including alewife and blueback herring, in the Winnicut River ecosystem. The primary objective for achieving this restoration goal would be to improve upstream and downstream fish passage within the Winnicut River, with a secondary objective of enhancing the overall function of the Winnicut River ecosystem. The feasibility of each option was assessed with respect to its impacts to adjacent infrastructure, groundwater and wells, recreational use, natural resources, and historical and archeological resources.

The Winnicut Dam is owned by the New Hampshire of Fish and Game Department (NHFGD). It is situated at the head-of-tide on the Winnicut River in Greenland, New Hampshire, and represents the only anthropogenic barrier to upstream fish movement along the main stem of the river. The dam currently restricts fish movement within the Winnicut River, which in turn affects other ecological systems that are dependent upon the fish populations for dispersal within the ecosystem.

Although a fish ladder was incorporated into the dam at the time of its construction in 1957, its design has proven to be inefficient in providing upstream passage for most diadromous and resident fish species. Because the fish ladder is currently only operated to accommodate upstream migration of anadromous river herring in the spring, it is of limited utility in providing a means of upstream passage for anadromous rainbow smelt and catadromous American eel. Cumulatively, the poor performance and limited window of operation of the existing fish ladder combined with lack of dedicated downstream fish passage has adversely impacted the use of the Winnicut River by diadromous and resident fish.

Three primary alternatives for achieving the project goals are presented in this Feasibility Study. Alternative A is the “No Action” alternative. Alternatives B and C present differing approaches intended to achieve the project goals.

Alternative A, the No Action alternative, does not meet the basic project goals of restoring resident and diadromous fisheries in the Winnicut River, but is included as a baseline for the purpose of comparing the affects of the other alternatives. This alternative avoids some short-term, temporary impacts associated with the other alternatives, but does not address impacts to fisheries associated with the Winnicut Dam, with the primary impact being the poor performance of the existing fish ladder. Under the No Action alternative, adverse impacts associated with the presence of the dam and the existing fish ladder would continue and would constitute a long-term impact to the natural resources dependent upon upstream and downstream fish passage and factors such as the loss of riverine habitat resulting from the presence of the Winnicut Dam.

Alternative B would involve the construction of an Alaska Steeppass technical fishpass in place of the existing Canadian step weir fish ladder at the Winnicut Dam. This alternative meets some of the projects needs through the implementation of improved fish passage at the Winnicut Dam, but does not provide for increased free-flowing riverine habitat or enhanced downstream fish passage.

Alternative C would involve the removal of the Winnicut Dam and the construction of a technical fishpass under the State Route 33 Bridge (Rte 33 Bridge). The alternative would meet the project goal through the improvement of upstream and downstream fish passage and the restoration of approximately 250 feet of the Winnicut River below the Rte 33 Bridge to riverine conditions. The restoration of the riverine habitat is particularly important for achieving project objectives associated with the restoration of rainbow smelt populations in the Winnicut River, as this species is dependent upon riverine habitat for spawning and is not capable of ascending most types of fishpass systems.

Alternative C is the preferred option based on its ability to achieve the project goals associated with the restoration of resident and diadromous fisheries in the Winnicut River ecosystem. Specific benefits of this alternative include the restoration of riverine habitat that is suitable and accessible for spawning by smelt and improved upstream and downstream fish passage.

The Feasibility Study Project Partners include the New Hampshire Office of State Planning (NHOSP), the NHFGD, the New Hampshire Department of Environmental Services (NHDES), the National Oceanic and Atmospheric Administration Restoration Center (NOAA), the University of New Hampshire, and the Coastal Conservation Association. Project Partners who actively participated in the Feasibility Study include NHOSP, NHFGD, NHDES, and NOAA.

The Feasibility Study was performed by Woodlot Alternatives, Inc. of Topsham, Maine, in coordination with Alden Research Laboratory, Inc. of Holden, Massachusetts, Public Archeology Library, Inc. of Pawtucket, Rhode Island, and Wright-Pierce, Inc. of Topsham, Maine.

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1.0 INTRODUCTION

Winnicut River upstream of the Winnicut Dam – April 2003

The Winnicut Dam is owned by the New Hampshire of Fish and Game Department (NHFGD) and is situated at the head-of-tide on the Winnicut River in Greenland, New Hampshire (Figure 1). It currently presents the only anthropogenic barrier to upstream fish movement along the main stem of the river. Because of this, the NHFGD has initiated investigations of potential means of restoring native, historic fish populations to the system. The purpose of the Winnicut Dam Removal Feasibility Study (Feasibility Study) is to evaluate means to achieve project goals associated with the restoration of diadromous[1] and resident fisheries in the Winnicut River ecosystem. The Feasibility Study was commissioned by the New Hampshire Office of State Planning (NHOSP) in coordination with the NHFGD, the New Hampshire Department of Environmental Services (NHDES), and the National Oceanic and Atmospheric Administration Restoration Center (NOAA).

The project goals include the restoration of diadromous and resident fisheries in the Winnicut River and enhancement of the overall ecological function of the river. As stated above, the purpose of the Feasibility Study is to develop and evaluate the feasibility of alternatives for achieving the project goals. The various alternatives were evaluated with respect to their ability to achieve the project goals as well as their potential impacts to the surrounding resources. Potential impacts to the following resources (constraints) were evaluated as part of the Feasibility Study:

- ecological;
- hydrology, hydraulics, and fluvial processes;
- groundwater;

[1] Diadromous fish have a well-defined pattern of migration between fresh and salt water, or vice versa, for spawning, feeding, and development.

- infrastructure;
- socio-economic;
- recreational; and
- cultural and historical resources.

Additional Project Partners include the University of New Hampshire and the Coastal Conservation Association. Project Partners who actively participated in the feasibility study include NHOSP, NHFGD, NHDES, and NOAA. The Feasibility Study was performed by Woodlot Alternatives, Inc. of Topsham, Maine, in coordination with Alden Research Laboratory, Inc. of Holden, Massachusetts, Public Archeology Library, Inc. of Pawtucket, Rhode Island, and Wright-Pierce, Inc. of Topsham, Maine.

1.1 PROJECT HISTORY

1.1.1 History of the Winnicut River Dam, Greenland, New Hampshire

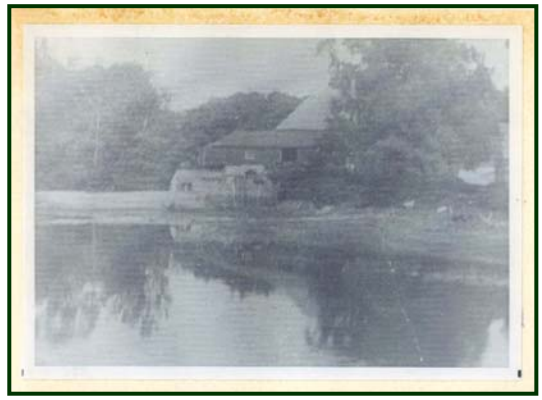
The current Winnicut Dam was constructed in 1957 at a location that had historically housed a dam since the mid-17th century. Following is a brief summary describing the history of the dam site. A more detailed history is provided in Appendix 1. The results of a title search on the Winnicut Dam are presented in Appendix 2.

Greenland's Early Days

The area that became the Town of Greenland in 1721 was initially part of Portsmouth and was first settled in the mid-17th century. The area's early economy was based on lumbering, fishing, farming, and maritime commerce. The brackish waters of the Winnicut River at Greenland created spawning conditions necessary for smelt and alewife to breed successfully, and fishing was an important source of food and income for early Greenland residents (SRRC 1981). The town's location near the southern shore of Great Bay made Greenland an ideal shipping port. Lumber that was harvested from inland areas and floated down the Winnicut and other rivers was processed there and exported to England (Hughes 2002).

History of the Dam

The first dam on the Winnicut in Greenland was constructed in the 1660s at the approximate site of the current dam. From the time of its construction until it was washed out in 1942, the original dam supported various industrial mills on both the east and west sides of the river. The first mill was a sawmill on the east side of the river, followed by the addition of a grist mill on the west side in 1685. It is believed that these mills, as well as a second mill constructed on the west side, were operated continuously by a variety of individual owners until about 1864, when all the mills on both sides of the river became the property of the Union Mills Corporation. The Union Mills Corporation operated the mills profitably until sometime between 1892 and 1895, when all three mill facilities burned. Sometime between 1898 and 1916, the east shore mill was rebuilt as both a sawmill and a grist mill, which appear to have been operated by various owners until the dam was washed out in 1942.



Mill on the Winnicut River (courtesy of Paul Hughes)

It appears that there was no dam in place on the Winnicut River in Greenland from 1942 until 1957, the year the current dam was constructed. During that time period, the river flowed unobstructed into Great Bay, though little is known about the conditions in the river and the types of fisheries that existed above and below the dam site.

The current dam was constructed in 1957 by the State of New Hampshire who had acquired flowage rights and the right to erect a dam in 1956. The State's apparent intent was to construct a dam to create waterfowl habitat and a slackwater impoundment for fish. Realizing that the dam would impede the upstream migration of anadromous fish from Great Bay, a Canadian step-weir fish ladder was constructed on the western side of the dam. It was soon clear, however, that the ladder's zigzagging pool configurations, steep drops between the pools, and high water turbulence presented a difficult obstacle to fish migrations. By 1965, after the anadromous fish runs had ceased, the state proposed improvements to the pool and ladder configuration, but those improvements were never implemented (NHDES 1965).

In 1959, two years after the construction of the current Winnicut Dam, the highway bridge located approximately 250 feet upstream was replaced with a larger bridge situated immediately upstream from the existing bridge. This work resulted in the placement of fill over an area of approximately 14,000 square feet within the Winnicut River and the raising of the stream channel bottom under the new bridge by approximately 7 feet. The volume and geometry of fill placed during the construction of the new bridge has constricted the river channel in the vicinity of the bridge, resulting in a backwater during flows in excess of approximately 150 cfs.

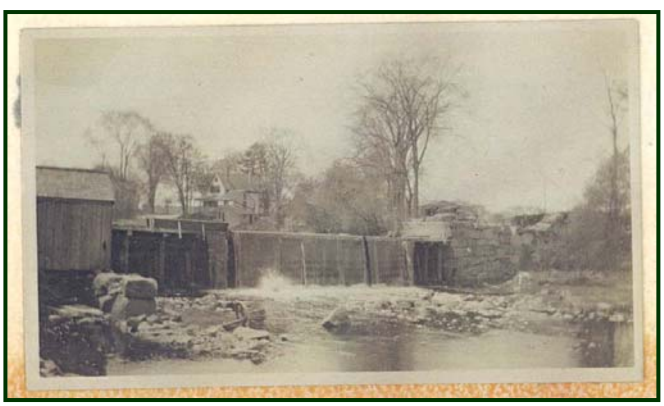
The only remnants of the previous dam to survive construction of the existing dam are the masonry wall that abuts the fish ladder on the west bank and part of the wing wall on the east bank at that end of the dam. The building on the east bank of the river, known as the Holmes Mill, was used for a time as administrative offices of the NHFGD, but the building gradually fell into disrepair and was eventually burned and razed in the 1980s as part of a fire training exercise (Cheri Patterson, NHFGD, personal communication 2003). Two fieldstone wall segments located on the east bank of the river may be the only visible remnants of the Holmes Mill.

Today, the dam remains in much the same form as when it was built in 1957. Waterfowl have returned to the area above the dam, as intended in its planning. The impoundment created above the dam is stocked with trout and is a popular area for fishing. Some river herring and rainbow smelt return to the base of the dam annually, but few are known to successfully negotiate the fish ladder.

A dam inspection performed as part of the Feasibility Study is included in Appendix 3.

1.1.2 The Winnicut River Watershed and Great Bay

The Winnicut River watershed presents a unique restoration opportunity in New Hampshire, as the Winnicut River is the only tributary river to the Great Bay estuary with a single extant dam. Given the lack of permitted point-source pollutant discharges within the watershed and the limited extent of development adjacent to most of the river, the Winnicut River can be considered the most pristine of the tributary rivers to the Great Bay estuary.



Dam on Winnicut River circa 1900 (photograph courtesy of Paul Hughes)

According to the NHDES Dam Removal and River Restoration Program, there are over 4,800 active and inactive dams in New Hampshire, and over 200 active and inactive dams within the Great Bay watershed (Figure 2). Some of these dams provide useful functions, such as hydroelectric power generation and water impoundment for municipal and industrial use. However, many of these dams are no longer capable of fulfilling their original purpose due to a variety of factors, such as the loss of water storage capacity due to sedimentation and poor water quality due to euthrophication. In addition, many of these dams represent financial liabilities to their owners due to maintenance needs and safety concerns.

The current Winnicut Dam occupies a site on the Winnicut River that has been host to a number of dams since European colonization of North America. These dams provided power for early industrial activities, including saw and grist mills. The current dam was constructed in 1957, apparently for the purpose of providing waterfowl habitat in the impoundment upstream of the dam. Although a Canadian step weir fish ladder was incorporated into the design and construction of this dam, the fish ladder is inefficient in providing for upstream passage of native fish in the Winnicut River.

Winnicut Dam and fish ladder at high tide – August 2003

New Hampshire fisheries personnel recognized soon after the construction of the dam that its presence had a negative effect on the Winnicut River's anadromous fish populations, specifically rainbow smelt (*Osmerus mordax*) and river herring (*Alosa* spp.). One measure that was considered to mitigate impacts to rainbow smelt was the construction of gravel pads in the river downstream of the dam for the purpose of enhancing spawning habitat. This was never implemented, however. Ongoing efforts have been made to improve the characteristics of the existing fish ladder for upstream passage by river herring have met with marginal success.

1.2 PROJECT GOALS

Project goals as established by the Project Partners are to:

- restore diadromous and resident fish populations in the Winnicut River; and
- enhance the overall ecological function of the Winnicut River.

This study presents information pertinent to achieving the stated project goals within the context of constraints associated with ecological, fluvial, groundwater, infrastructure, socio-economic, and cultural and historical factors. The project goals are discussed in detail below.

1.2.1 Restoration of Fisheries

The restoration of native fisheries within the Winnicut River, particularly diadromous fish, would likely benefit the overall ecological function of the Winnicut River and Great Bay and, in turn benefit recreational and commercial fisheries in Great Bay and in the Gulf of Maine. The Winnicut Dam currently restricts movement of fish between the riverine and estuarine reaches of river. The existing fish ladder has poor performance characteristics regarding upstream passage of target diadromous fish species, and it is only operated on a seasonal basis. In addition, there are no provisions for the downstream passage of migrating fish. During periods of low flow in the Winnicut River (i.e., less than 1 cubic-foot-per-second [cfs]), when most of the flow past the dam results from seepage through the stoplogs, downstream fish passage is blocked.

Restoration objectives for diadromous fisheries as presented in this study are primarily focused on the anadromous[2] rainbow smelt and river herring, specifically alewife (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*). The catadromous[3] American eel (*Anguilla rostrata*) would also likely benefit from improved access to the Winnicut River upstream of the Winnicut Dam. Resident fish populations in the Winnicut River, such as black bass (*Micropterus* sp.), chain pickerel (*Esox niger*), and sunfish (*Lepomis* sp.), would also likely benefit from the proposed restoration goals through improved access

Rainbow Smelt (NHFGD)

[2] Anadromous fish spawn in fresh water and spend a portion of their lives in salt water

[3] Catadromous fish spawn in salt water and spend a portion of their lives in fresh water

within the lower reaches of the river and increased forage due to increased populations of young-of-year river herring. Benefits to resident fish populations, however, are considered incidental to achieving the primary goal of restoring diadromous species in the Winnicut River.

Anadromous Fisheries

The existing fish ladder at the Winnicut Dam precludes the upstream passage of rainbow smelt, effectively restricting their spawning activity in the Winnicut River to the tidally influenced reach of the river below the dam. The primary means of achieving the stated restoration goal for rainbow smelt, therefore, requires either eliminating barriers to their upstream passage or providing additional spawning habitat within the Winnicut River.

River herring are marginally successful in achieving upstream passage using the existing fish ladder at the Winnicut Dam. However, this marginal success requires nearly constant maintenance of the existing fish ladder. Because of these maintenance requirements, the fish ladder is operated only during the normal spawning migration period for river herring. This limited operational window is not effective in providing upstream passage for all resident fish populations.

The lack of a dedicated means for downstream fish passage at the Winnicut Dam also has deleterious effects on river herring due to the configuration of the dam. During periods of lower flow, which can occur during the downstream migration of young-of-year herring, most of the flow past the dam occurs over the stoplog bay situated next to the spillway and the fish ladder. At low tide, flow over the stoplogs falls onto the concrete apron at the downstream base of the dam, resulting in the potential for injury and/or mortality of downstream migrating fish.

The primary means of restoring or improving river herring populations, therefore, requires either the elimination of barriers to their passage or installing effective fish passage at existing barriers along the river for both upstream and downstream-migrating fish.

Catadromous Fisheries

Catadromous American eel currently occur in the Winnicut River and may be successful at circumventing the Winnicut Dam during upstream migration when the fish ladder is not in operation. During the course of this study, young-of-year eels (elvers) were observed in the fish ladder. However, the only flow at that time was from leakage through the stoplogs at the exit (i.e., upstream end) of the fish ladder. It was not determined whether the elvers observed were successful at passing through gaps in the fish ladder stoplogs and continuing upstream. Both adult eels and elvers may circumvent the dam by making brief, overland forays; however, this can result in excessive mortality due to predation. The primary means of restoring or improving American eel populations, therefore, requires either the elimination of barriers to their passage or installing effective passage at existing barriers along the river.

Resident Fisheries

There are currently no provisions for resident fish species such as bass, pickerel, and sunfish to move from the brackish reach of the Winnicut River downstream of the Winnicut Dam to the upstream freshwater reaches except when the fish ladder is in operation during river herring migration. Because of the limited habitat for freshwater species downstream of the dam, it is likely that there is a high incidence of mortality associated with resident fish passing over the dam due to stranding, predation at low tide, and intolerance to higher salinities. Enhancing opportunities for these fish to ascend back upstream to the freshwater reaches of the river would reduce this mortality, if it occurs. In addition, resident fish populations would benefit from restored diadromous fisheries (i.e., river herring) through access to a larger forage base provided by young-of-year diadromous fish.

Commercial and Recreational Factors Associated with the Diadromous Fishes of the Winnicut River

The diadromous fish species of the Winnicut River, particularly river herring, are the basis of a dedicated commercial fishery along the coast of New Hampshire and in the Gulf of Maine. These fish also provide an important forage base for fish sought by commercial and recreational fishermen, such as striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*). Historically, rainbow smelt have provided an important seasonal recreational fishery throughout Great Bay. A decline in rainbow smelt numbers, however, has apparently threatened the viability of both the recreational and commercial fisheries associated with this species.

Data compiled as part of the New Hampshire's Marine Fisheries Coastal Netter's Program, which requires the mandatory reporting of fish caught in New Hampshire's coastal and estuarine waters, indicates that landings of American eel and river herring have declined during the years from 1998 through 2002 (Table 1). While the estimated poundage of rainbow smelt taken during the Great Bay estuary ice fishery over the period from 1978 through 2001, as reported by the state of New Hampshire, does not indicate a trend towards decreased numbers of fish, the overall mean estimate of smelt egg deposition in 2002 was below the long-term average (Appendix 4).

Table 1: New Hampshire Coastal Netter's Program Data

Species	Weight of Harvest (pounds)				
	1998	1999	2000	2001	2002
American Eels	422	246	310	185	61
Rainbow Smelt	-	37	27	113	-
Dogfish	-	-	-	153,400	129,000
River Herring	25,993	19,049	22,141	14,129	13,617
Yearly Total (all species)	28,204	27,565	35,255	195,662	147,573
Percent of River Herring Based on Yearly Total	92%	69%	63%	7%	9%
Yearly Total Minus Dogfish	28,204	27,565	35,255	42,262	18,573
Percent of River Herring Based on Yearly Total Minus Dogfish	92%	69%	63%	33%	73%

"-" = No Data

The relative importance of river herring to New Hampshire's coastal fishery can be evaluated based upon the percentage river herring relative to the total catch. This data indicates that in 1998, 1999, and 2000, river herring comprised 92-, 69-, and 63-percent of the total catch in, respectively (Table 1). In the 2001 and 2002, the percentage of river herring dropped to 7- and 9-percent, respectively, due largely to a fishery for dogfish (*Squalidae and Triakidae*) in New Hampshire's coastal waters. If the dogfish catch is subtracted from the total catch for 2001 and 2002, the percentage of river herring increases to 33- and 73-percent, respectively, for these years.

On a broader scale, the commercial catch of river herring off the eastern coast of the United States has declined precipitously since the 1960s. While the nominal catch of river herring in the Gulf of Maine and mid-Atlantic coast of the United States averaged 27,5000 tons per year during the 1960s, the average nominal catch from 1994 to 1998 was 550 tons per year (Appendix 4). This difference represents a fifty-fold decrease in the commercial catch of river herring in these waters between the 1960's and the late 1990s.

1.2.2 Enhanced Ecological Function

The Winnicut River system, just like any river, includes a wide variety of aquatic and terrestrial habitats home to a large number of vertebrate and invertebrate animal species. While the Winnicut Dam has resulted in the obvious restriction of sea-run fish within the system, it has also resulted in the disruption of ecological processes and functions associated with those fish resources.

For example, most species of New England freshwater mussels have a parasitic stage during which the larvae must attach to the gills and fins of specific species of fish in order to successfully transform to juvenile mussels. Any restriction of the movement of potential host fish species, therefore, has a direct impact on the potential distribution of those mussel species dependant upon them. Conversely, restoration of natural, historic fish passage in the Winnicut River can result in the re-establishment of the natural distribution of native mussels in the river. These, in turn, can provide food resources for a number of medium-sized aquatic and semi-aquatic predators. Consequently, the restoration of historic fish populations in the river can have many secondary, less obvious benefits to the ecology of the system.

Other effects of the Winnicut Dam that could alter ecological functions in the system include reduced stocks of forage fish (e.g., young-of-year river herring), reduced stocks of higher trophic level forage species (e.g., river herring), reduced nutrient cycling.

1.3 METHODS OF FEASIBILITY STUDY

The purpose of the Feasibility Study as established by the Project Partners is to examine the feasibility of various alternatives for restoring diadromous and resident fish populations in the Winnicut River. The process by which the Feasibility Study was carried out is presented below.

1.3.1 Proposed Alternatives

The process of developing alternatives for the Feasibility Study was based on an initial evaluation of conceptual alternatives followed by the subsequent development of primary alternatives. Eight conceptual alternatives were initially proposed and evaluated in consultation with the Project Partners to determine whether it merited advancement to the status of primary alternative.

Five alternatives were rejected after an initial evaluation because they clearly did not meet the project goals or were not feasible based on project constraints (e.g., engineering limitations, highway safety). Three were eventually advanced as primary alternatives. The primary alternatives were subsequently developed in more detail and their specific strengths and weaknesses compared.

1.3.2 Feasibility Assessment

All of the alternatives developed in the course of the Feasibility Study were evaluated based on constraints associated with ecological, fluvial, groundwater, infrastructure, socio-economic, and cultural and historical factors. Potential impacts associated with the conceptual project alternatives were assessed based on readily apparent factors associated with the project goals and constraints. This assessment culminated with the selection and subsequent development of the primary alternatives. The primary alternatives were then developed in more detail and evaluated through a comparison of benefits and impacts associated with the project goals and constraints.

The evaluation of the primary *ecological* factors considered whether the project goals associated with the restoration of smelt and river herring populations and ecological continuity in the Winnicut River could be achieved through the implementation of the primary alternatives. Other ecological factors evaluated in this study included impacts to adjacent wetland and faunal communities. *Fluvial* factors evaluated in this study included potential changes to peak flood elevations, scour, sediment transport, and effects to adjacent wetlands. *Groundwater* factors that were evaluated included the potential response of the aquifer immediately adjacent to the Winnicut River in the reach impounded by the Winnicut Dam. Potential impacts to adjacent *infrastructure* were evaluated by considering factors associated with commercial and residential wells, the Rte 33 Bridge over the Winnicut River, and the withdrawal of water from the existing impoundment for fire-suppression. *Socio-economic* factors evaluated in this study included recreational usage of the Winnicut River in the vicinity of the dam, such as fishing and boating. *Cultural and historical factors,* including archeological resources in the vicinity of the dam, architectural resources of the dam, and adjacent structures, were evaluated.

2.0 ALTERNATIVES

2.1 INTRODUCTION

Eight conceptual alternatives for achieving the project goals were proposed, developed, and evaluated as an initial part of this study. Five of these conceptual alternatives were rejected for further analysis based on an initial feasibility evaluation. Three primary alternatives, including a No Action alternative, were subsequently developed in more detail and their specific strengths and weaknesses compared based on the project goals and constraints.

2.2 CONCEPTUAL ALTERNATIVES CONSIDERED BUT REJECTED

2.2.1 Removal of the Winnicut Dam without Provisions for Upstream Fish Passage at the Rte 33 Bridge

Implementation of this alternative would provide approximately 250 feet of additional spawning habitat for smelt between the dam and the bridge but it would not allow passage of smelt or river herring upstream of the Rte 33 Bridge due to high flow speeds over the existing rock riprap under the bridge. This alternative was not pursued further because it would provide very limited benefits associated with fisheries and ecological restoration goals.

2.2.2 Partial Breaching of the Winnicut Dam without Provisions for Upstream Fish Passage

Implementation of this alternative would consist of a partial breaching of the existing dam to provide for fish passage at the dam while maintaining a backwater at the downstream end of the channel under the Rte 33 Bridge. The purpose of this backwater would be to improve the potential for upstream fish passage under the bridge by improving hydraulic conditions in the steeper portion of the channel at its lower end.

Implementation of this alternative would require migrating fish to ascend both the breached dam and the channel under the Rte 33 Bridge when moving upstream. It would provide no likely gain in riverine habitat suitable for spawning by rainbow smelt (i.e., that area between the dam and Rte 33). Therefore, this alternative was not pursued.

2.2.3 Removal of the Winnicut Dam and Restoration of the Natural Channel Under the Rte 33 Bridge

The economical restoration of a natural streambed under the Rte 33 Bridge that has suitable flows for fish passage but does not impair highway safety was the critical component of this alternative. Although implementation of this alternative would achieve the project goals pertaining to ecological restoration, it was not pursued because of readily apparent effects pertaining to socio-economic, recreational, and infrastructure constraints. These effects would likely include substantial modification to the Rte 33 Bridge and impacts to prevailing recreational uses within the Winnicut River.

2.2.4 Removal of the Winnicut Dam and Construction of a Traditional Technical Fishpass Under the Rte 33 Bridge

Implementation of this alternative would require that the traditional technical fishpass (e.g., Denil, Alaska Steeppass, pool and weir) be placed adjacent to the existing channel under the Rte 33 Bridge. Specific drawbacks of this design include high potential for debris fowling of the technical fishpass, difficulty of maintaining optimum flows in the technical fishpass, and inflexibility with regard to future changes in the bridge substructure geometry. Therefore, this alternative was not pursued.

2.2.5 Removal of the Winnicut Dam and Construction of a Nature-Like Fishpass Between the Rte 33 Bridge and the Winnicut Dam

The design of a nature-like fishpass would require the placement of a large volume of fill on top of the existing streambed between the dam and the bridge. This placement of the nature-like fishpass would eliminate what would otherwise be suitable spawning habitat for rainbow smelt within the limits of the existing impoundment between the dam and the Rte 33 Bridge following removal of the dam (Figure 3). Therefore, this alternative was not pursued.

2.3 PRIMARY ALTERNATIVES

The following primary alternatives were developed and evaluated as part of this study.

2.3.1 Alternative A – No Action

Implementation of Alternative A would not achieve the project goals and would result in no impacts associated with the project constraints. This alternative was put forth as a baseline for comparison of the other primary alternatives.

2.3.2 Alternative B – Improved Upstream Fish Passage at the Winnicut Dam

Alternative B would involve improved upstream fish passage at the Winnicut Dam through the construction of a new, technical fishpass and decommissioning of the existing fish ladder at the Winnicut Dam. The fishpass would most likely be an Alaska Steeppass structure within the concrete superstructure surrounding the existing Canadian step weir fish ladder and would require annual maintenance (Figure 4). This alternative was developed as a primary alternative because it represents a typical means of mitigating problems associated with fish passage at dams.

2.3.3 Alternative C – Removal of the Winnicut Dam and Construction of a Technical Fishpass Under the Rte 33 Bridge

This alternative was forwarded as a primary alternative because fish passage would be achieved with the least cost to potential future rainbow smelt spawning habitat between the site of the existing dam and Rte 33. That is, the fish passage structure would be small and not be placed on top of the actual river channel, as would be required for a nature-like structure (Figure 5). The technical fishpass would be operated year-round and would require minimal maintenance. Additionally, passage would be possible for both upstream and downstream-migrating fish.

3.0 AFFECTED ENVIRONMENT

3.1 INTRODUCTION

This section describes conditions pertinent to the Feasibility Study in and adjacent to the Winnicut River in the vicinity of the Winnicut Dam. The information presented in this section addresses ecological, hydrologic, groundwater, infrastructure, socio-economic, and recreational resources as they relate to the feasibility of achieving the project goals of ecological restoration within the Winnicut River watershed. Historical and cultural resources were also evaluated as part of this study; specific information on these resources is presented in Appendix 1. An assessment of impacts to these resources that may result from the implementation of the primary alternatives is described in Section 4.0.

3.2 ECOLOGICAL RESOURCES

3.2.1 Fisheries

The Winnicut River hosts a variety of fish species, including migratory fish such as rainbow smelt, river herring, and American eels, and resident fish such as black bass, pickerel, and sunfish. The NHFGD maintains a recreational put-and-take fishery for trout in the Winnicut River each year, but the trout do not persist in the river year-round due to high water temperatures.

Fisheries resources of the Winnicut River were assessed to provide information for the evaluation of the primary alternatives relative to their ability to achieve the project goals. This assessment addresses factors pertinent to the use of the Winnicut River by endemic diadromous fish, as represented by anadromous rainbow smelt and river herring (alewife and blueback herring) and the catadromous American eel. While the restoration goals for diadromous fisheries in the Winnicut River include both anadromous and diadromous species, the primary focus of this evaluation is anadromous rainbow smelt and river herring. This determination was made based on the assumption that any changes providing increased access to upstream habitat in the Winnicut River for smelt and river herring would result in a commensurate increase in access for eels.

This study does not evaluate factors specific to resident warmwater fish of the Winnicut River, such as bass, pickerel, and sunfish.

The use of the Winnicut River by coldwater fish that are currently stocked by the NHFGD as part of a put-and-take fishery, as represented by various trouts (*Salmonidae*), were not evaluated as part of this study except as a recreational resource.

Anadromous Fisheries

The life history of anadromous fish is characterized by spawning in freshwater and rearing in saltwater. Anadromous fish evaluated as part of this study include rainbow smelt and river herring. Both smelt and river herring are capable of maintaining viable landlocked populations, with lacustrine environments filling the role of the saltwater habitats used by stocks of fish with access to the coast. The Winnicut River is too small, however, to support landlocked populations of rainbow smelt or river herring.

The diadromous fish of the Winnicut River, and particularly the anadromous river herring, are the target of dedicated commercial fisheries in the coastal waters of New Hampshire and along much of the east coast of the United States. In addition, all of the life stages of rainbow smelt and river herring provide forage for commercial and recreational fish in the Great Bay estuary and the Gulf of Maine.

<u>Rainbow Smelt</u>

Various year classes of Rainbow smelt (NHFGD)

Rainbow smelt spawn in the Winnicut River from mid-March through early May. While smelt are capable of spawning in fresh and brackish waters, their eggs can be adversely affected by higher salinities. Preferred spawning habitat for rainbow smelt is characterized by coarse substrates (e.g., rock, gravel) and swift flowing water. Observations made in the course of the Feasibility Study suggest that suitable spawning substrates are present in the Winnicut River in the inundated reach of river immediately upstream of the Winnicut Dam and at locations upstream of the impoundment. However, the existing fish ladder at the Winnicut Dam precludes the upstream passage of rainbow smelt, effectively restricting their spawning habitat in the Winnicut River to a tidally influenced reach of the river approximately 1,000 feet long immediately downstream of the dam.

Prior to the construction of the Winnicut Dam in 1957, populations of smelt in the river sustained a recreational fishery. It is likely that this fishery benefited substantially from access to spawning habitat in the Winnicut River upstream of the existing dam and Rte 33 Bridge during the period between 1941 when the previous dam washed out and 1957 when the current dam was constructed. Note that the configuration of the upstream bridge during this period would most likely have allowed for the passage of adult smelt to upstream spawning habitat. Following the construction of the Winnicut Dam in 1959, a number of scenarios were developed for improving smelt spawning habitat downstream of the dam, such as the construction of gravel spawning beds. These scenarios were never implemented, however.

Means for achieving the restoration goals for rainbow smelt in the Winnicut River require the elimination of existing barriers to upstream passage. Removal of the Winnicut Dam would provide approximately 250 feet of additional spawning habitat in the Winnicut River. Providing smelt with access to the Winnicut River upstream of the Rte 33 Bridge would require the removal of the Winnicut Dam and the restoration of a the natural stream channel gradient under the Rte 33 Bridge. This would result in the loss of the existing impoundment upstream of the bridge.

<u>River Herring (Blueback Herring and Alewife)</u>

River herring spawn in the Winnicut River from mid-April through the end of June, with alewife typically preceding the blueback herring by a few weeks. Alewife prefer to spawn in still water, and will resort to spawning in quiet water along the margins of rivers if ponds or lakes are not available. Hard substrates are preferred for spawning habitat.

Alewife (NHFGD)

Blueback herring prefer to spawn in riverine habitats with swift currents over hard substrates, and specifically avoid spawning in lentic (i.e., still water) habitat, particularly in their sympatric range with alewife. The larvae of blueback herring are tolerant of a wide range of salinities, allowing them to use freshwater and marine areas at early life stages.

Blueback Herring (NHFGD)

Preferred spawning habitat for smelt is characterized by coarse substrates (e.g., rock, gravel) and swift flowing water. Observations made in the course of the Feasibility Study suggest that suitable spawning substrates are present in the Winnicut River in the inundated reach of river immediately upstream of the Winnicut Dam and at locations upstream of the impoundment. However, the existing fish ladder at the Winnicut Dam precludes the upstream passage of rainbow smelt, effectively restricting their spawning habitat in the Winnicut River to a approximately 1,000-foot long tidally influenced reach of the river immediately downstream of the dam.

Observed conditions indicate that the Winnicut River upstream of the Winnicut Dam provides a substantial area of habitat suitable for spawning by alewife and blueback herring. Suitable substrate conditions for spawning are present in the Winnicut River from the south side of Camp Gundalow upstream to at least the Winnicut Road Bridge. Because of its preference for spawning in lotic habitats, these upper reaches of the Winnicut River are more suited to spawning by blueback herring, although alewife would likely also ascend into this reach of the river and spawn in eddies and newer beaver flowages. Intermittent areas of gravel substrate are also available in small areas between the Winnicut Dam and Camp Gundalow, and would provide ideal spawning habitat for alewife.

While river herring may spawn in the Winnicut River downstream of the Winnicut Dam, the potential for high salinities and predation of eggs by birds at low tide likely result in marginal success.

Although river herring are generally successful in ascending fishpass structures, they have had limited success using the existing fish ladder at the Winnicut Dam (Cheri Patterson, NHFGD, personal communication 2003). Additionally, the Winnicut Dam lacks a dedicated means for downstream passage, which may also have deleterious effects on river herring due to the configuration of the dam. During periods of lower flows, which can coincide with the downstream migration of young-of-year herring, most of the flow past the dam occurs over the stoplog bay situated between the spillway and the fish ladder. At low tide, flow over the stoplogs falls onto the concrete apron at the downstream base of the dam, resulting in the potential for injury and/or mortality of downstream migrating fish.

Catadromous Fisheries

The life history of catadromous fish is characterized by spawning in salt water and rearing in freshwater. The only catadromous fish evaluated as part of this study is the American eel.

American Eel

American eels spawn in the Sargasso Sea south of Bermuda in the Atlantic Ocean. At approximately one year of age the young-of-year larval eels metamorphose into elvers and begin a migration to the eastern coast of North America, where they take up residence along the coast in saltwater, estuarine, and freshwater habitats. The eels may spend 5 to 20 years maturing before returning to the Sargasso Sea to reproduce, at which time they are typically between one and three feet long.

American eel swimming along the downstream face of the Winnicut Dam – August 2003

Both elvers and adult America eels currently use the Winnicut River for rearing and growth. In the course of the Feasibility Study, elvers were observed in the Winnicut Dam fish ladder and adult eels were observed swimming along the downstream toe of the dam. While the presence of eels upstream of the dam was not confirmed for this study, it is likely that some elvers and adult eels circumvent the dam by making brief, overland movements, which have been documented for this species.

While both adult and juvenile (elver) eels are very adapt at circumventing impediments to upstream migration, such as dams, typical technical fishpasses designed to accommodate river herring, such as the Alaska steeppass and Denil, are not best suited for passing elvers due to high flow speeds.

American eel would likely benefit from improved access to the Winnicut River through the elimination of barriers to their upstream passage or installing effective upstream fish passage at existing barriers along the river. Eels would also benefit from additional forage resulting from increased numbers of smelt and river herring in the Winnicut River.

Resident Fisheries

Resident game fish in the Winnicut River include black bass, chain pickerel, and sunfish. While it is likely that the pickerel and sunfish are indigenous, black bass would have been introduced through stocking. Trout are annually stocked in the Winnicut River upstream of the Winnicut Dam as part of a put-and-take fishery, but do not persist in the system due to unsuitably high water temperatures during the summer.

3.2.2 Wetlands

Woodlot Alternatives surveyed wetland habitats along portions of the Winnicut River in 2003 to aid in the description of the affected environment and the evaluation of the potential effects of removing the Winnicut River Dam. The survey was done by canoe, and included the identification of the major wetland systems and types and the available wildlife habitats associated with the river. Both riverine and adjacent palustrine wetland types were considered. Following is a summary of the wetland resources associated with the survey area. The results of the wetland survey are provided in more detail in Appendix 5.

The wetland survey included the section of river extending from the dam approximately 4 miles upstream (Figure 6). This section can be divided into three reaches, each with its own distinct assemblage of wetland community types[4]. The shoreline communities currently assumed to be influenced by the backwater effects of the impoundment (i.e., Reach 3) received more intensive investigation, as these areas would be expected to be most influenced by the dam's removal. Data collected from river sections upstream of the impoundment are intended to provide a broad characterization of some of the aquatic habitats that would be available to anadromous fish populations if the dam were to be removed.

Reach 1 is the southern most section of the survey area and represents the area farthest upstream from the dam. This area consists primarily of flooded beaver (*Castor canadensis*) flowages caused by numerous active beaver dams within the river channel. These flowages consist of open water areas containing abundant shallow emergent and aquatic vegetation. Purple loosestrife (*Lythrum salicaria*) and common cattail (*Typha latifolia*) are two of the dominant emergent species that occur in the shallows, while pickerel weed (*pontederia cordata*), arrowhead (*Sagittaria latifolia*), and bur-reed (*sparganium* sp.) are common in the deeper emergent areas. Common waterweed (*Elodea canadensis*), coon tail (*Ceratophyllum demersum*), and water milfoil (*Myriophyllum* spp.) are the primary aquatic pants occurring in the open water areas. Reach 1 also includes several segments containing riffle habitat.

Reach 2, the middle section of the survey area, consists primarily of old beaver flowages, typically referred to as "beaver meadows". These flowages, which appear to have been

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[4] Wetland types and communities follow: Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States*. US Department of the Interior, Washington, DC. FWS/OBS-79/31.

abandoned by the beavers 5 to 10 years ago, are now primarily floodplain wetlands dominated by reed canarygrass (*Phalaris arundinacea*). However, shrubs are beginning to reestablish themselves within the meadows, creating a mixture of emergent and scrub-shrub communities. The river channel bisects the meadows, and is 3 to 8 feet wide and slow-moving within this reach.

Reach 3 consists of the first 4,000 (+/-) feet of the river upstream of the dam, which essentially comprises the limits of the impoundment (Figure 6). This reach includes a mix of both riverine and palustrine wetland communities. Open water segments occur throughout Reach 3, exhibiting limited vegetative growth. Aquatic beds, which contain both floating plant species such as bladderworts (*Utricularia* spp.) and rooted plants such as pondweeds (*Potamogeton* spp.), extend from the shoreline out into the deeper water. The riverine emergent community, which occurs along shallow shoreline areas, in small coves, and at the mouths of tributaries within Reach 3, is primarily made up of arrowheads (*Sagittaria* sp.), pickerelweed, and bur-reeds.

Small palustrine emergent communities occur along the edges of the River within Reach 3. Vegetation within this wetland type includes grasses such as bluejoint (*Calamagrostis canadensis*), sedges (*Carex* spp.), and other herbaceous vegetation such as common cattail. Scrub-shrub communities also occur at scattered location along the shore of Reach 3, with red osier dogwood (*Cornus sericea*), silky dogwood (*Cornus amomum*), speckled alder, and willows (*Salix* spp.) being the dominant species. At some locations, the scrub-shrub communities transition to forested floodplain wetlands dominated by red maple (*Acer rubrum*). These floodplain swamps further transition into infrequently-flooded floodplain forests dominated by basswood (*Tilia americana*), red maple, red oak (*Quercus rubra*), American elm (*Ulmus americana*), and shagbark hickory (*Carya ovata*).

The wetland riverine and palustrine wetland systems within the survey area have the ability and opportunity to perform several wetland functions and values. These include primarily floodflow control, water quality control (sediment, nutrient and toxicant retention), shoreline stabilization, production export, fish habitat, wildlife habitat, and recreational opportunities. A more detailed discussion of wetland functions and values can be found in Appendix 5.

3.2.3 Wildlife

Reconnaissance level wildlife observation surveys were made during a number of site visits. In August 2003, Woodlot recorded all wildlife species observed during a canoe survey of the river. The survey area was from the dam to a point approximately 4 miles upstream. A variety of wildlife species were observed within the survey area, including species that are dependent upon wetland/aquatic habitats and those that use these communities opportunistically (see Table 2). The use by other species can be inferred by the presence of specific habitat types. A review of readily available information indicated that there is no mapped habitat for known rare, threatened, or endangered wildlife species in the survey area.

White tailed deer (*Odocoileus virginianus*) utilize both the wetland communities as well as the adjacent upland areas when foraging. The barred owl (*Strix varia*), although not necessarily dependent upon wetland communities, are often found in riparian areas such as those in the survey area. They were observed on two occasions within the survey area. This species primarily forages in forested upland communities, but often nests in riparian areas. Similarly, the raccoon (*Procyon lotor*) uses a variety of habitats, but den sites are often located near water. Many other species observed within the survey area are dependent upon wetland/aquatic communities for at least part of their life cycle.

Amphibian species such as the green frog (*Rana clamitans*) are typically found in riparian or palustrine habitats that have open water interspersed with aquatic/emergent vegetation. This type of habitat occurs throughout the survey area, although Reaches 1 and 2 may have greater availability than Reach 3. Both the snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*) are likely to occur throughout the survey area in association with the riparian and palustrine open water communities.

Belted kingfishers (*Ceryle alcyon*) may forage along the river in areas of open water. Black ducks (*Anas rubripes*) and mallards are likely to occur throughout the survey area, particularly in areas of relatively shallow water where these species prefer to forage. Wood ducks also may be found throughout the survey area, but are more likely to be present in Reach 1 in association with the beaver flowages. Both willets (*Catoptrophorus semipalmatus*) and greater yellowlegs (*Tringa melanoleuca*) were observed in Reach 3 during the annual maintenance of the dam when the water level in the headpond was lowered. However, the foraging habitat (i.e., exposed shoreline) for these species is not available in the survey area except during these scheduled drawdowns. These species and other shorebirds typically occur downstream of the dam where mudflats are exposed during daily low tides. Ospreys occur primarily in the lower part of Reach 3 where there is sufficient open water area in which this species can forage.

Beavers (*Castor canadensis*), muskrats (*Ondatra zibethicus*), and river otters (*Lontra canadensis*) were observed and may occur throughout the survey area in association with the river channel. The beavers are currently present in Reach 1 and are very active there building and maintaining dams. Muskrats are typically associated with areas of dense emergent vegetation along the river or the beaver flowages. River otters were observed feeding on freshwater mussels and may occur throughout the survey area.

Table 2: Wildlife species observed within the Survey Area.

Class	Common Name	Scientific Name
Amphibians	green frog	*Rana clamitans*
	bullfrog	*Rana catesbeiana*
	pickerel frog	*Rana palustris*
Reptiles	snapping turtle	*Chelydra serpentina*
	painted turtle	*Chrysemys picta*
Birds	barred owl	*Strix varia*
	belted kingfisher	*Ceryle alcyon*
	black duck	*Anas rubripes*
	greater yellowlegs	*Tringa melanoleuca*
	mallard	*Anas platyrhynchos*
	osprey	*Pandion haliaetus*
	willet	*Catoptrophorus semipalmatus*
	wood duck	*Aix sponsa*
Mammals	beaver	*Castor canadensis*
	muskrat	*Ondatra zibethicus*
	raccoon	*Procyon lotor*
	river otter	*Lontra canadensis*
	white-tailed deer	*Odocoileus virginianus*

3.2.4 Endangered Species Habitat

No dedicated surveys were performed to look for rare plant or animal species. Based on a request to the New Hampshire Natural Heritage Bureau (NHNHB) for information on rare species and exemplary natural communities, two natural communities and three plant species were identified within or adjacent to the project area on the Winnicut River. This information is presented in Appendix 5.

3.3 HYDROLOGY, HYDRAULICS, AND FLUVIAL PROCESSES

3.3.1 General Hydrology of the Winnicut River Watershed

The Winnicut River originates in the coastal plain of New Hampshire and flows north into the Great Bay estuary, from which its waters pass into the Gulf of Maine. The entire watershed is contained within the state of New Hampshire and encompasses approximately 14.2 square miles. The headwaters of the river are predominantly comprised of marshes bounded by low-lying hills. Based on a review of United State Geological Survey (USGS) 7.5-minute topographic maps, there are no named ponds or lakes with surface areas greater than 2 acres within the watershed.

The highest point in the drainage basin appears to be along the western boundary of the watershed in the vicinity of Rollins Hill in Stratham, with an elevation of approximately 200 feet (NAVD-88). The average slope of the river is approximately 6 feet per mile, as determined from points located at 10 percent and 85 percent of a line drawn along the river channel to a point along the boundary of the watershed between Dows Corner in Exeter and Rollins Hill in Stratham. Along the reach of river between the Winnicut Dam and the upstream limit of the backwater, approximately 7,500 feet upstream, the slope of the streambed increases to approximately 9 feet per mile, although this is not readily apparent as this reach is typically inundated.

Soils within the watershed are primarily comprised of unconsolidated glacial till and stratified drift and marine deposits. Approximately 4 square miles of overburden aquifers comprised primarily of fine or coarse-grained stratified drift are identified within the watershed. Based on soil classification, approximately 5 square miles of the watershed is comprised of wetlands (GeoInsight 1999).

The average annual precipitation and pan evaporation rates in the vicinity of the Winnicut River watershed are estimated to be 48.8 and 35.71 inches per year, respectively (GeoInsight 1999). Pan evaporation rates are determined using a standardized methodology and are typically applied to the determination of evaporation from natural systems using a 'pan coefficient.' Assuming a pan coefficient of 0.70, the estimated annual evaporation from surface water bodies (e.g., ponds) in the vicinity of the Winnicut River is approximately 25 inches per year (GeoInsight 1999). Based on this value, an effective surface area of 15 acres (approximate) for the impoundment upstream of the Winnicut Dam, and the assumption that this evaporation is equally distributed over a 90-day period (e.g., summer), the average loss of water from the impoundment is 0.18 cfs.

In comparison to other rivers entering Great Bay and to other coastal rivers along the New England coast in general, the Winnicut River appears to have experienced minimal anthropogenic impacts. While rivers in the vicinity of the Winnicut River have experienced alterations in base flows, the generally low gradient of the river has apparently buffered impacts typically associated with consumptive surface water and groundwater withdrawals. While there are likely some non-point source discharges of agricultural waste into the Winnicut River resulting from agriculture usage within its watershed, the lack of point source commercial or municipal waste discharges is fairly unique and contribute to a relatively healthy riverine system.

3.3.2 Hydrology of the Winnicut River in the Vicinity of the Winnicut Dam

A hydrologic analysis was performed to provide information for the evaluation of impacts associated with the existing and alternative scenarios for the Winnicut Dam. The analysis is comprised of two distinct components: 1) the evaluation of flows associated with extreme hydrologic events (i.e., flood events); and 2) the evaluation of flows during periods associated with annual finfish spawning migrations.

Peak Flow Analysis

An evaluation of peak flow hydrology was performed to provide information pertinent to the evaluation of performance characteristics of the existing dam (e.g., spillway capacity) and other structures along the Winnicut River. Because the USGS gaging station on the Winnicut River has been in place for only two years, data obtained from this gaging station is not suitable for the determination of peak flows on the Winnicut River. Therefore, the peak flow analysis was performed using regional regression equations developed by the USGS and incorporated into the National Flood Frequency (NFF) computer software program. The results of this analysis are in general agreement with previous hydrologic analyses of the Winnicut Dam (Table 3).

Table 3: Peak Flows

Return Interval (years)	Peak Flow (cfs)
2	230
5	360
10	470
25	640
50	780
100	960
500	1490

Hydrologic Conditions During Target Fish Species Migration Periods

Hydrologic conditions during the target fish species migration periods were evaluated to provide information pertinent to the evaluation and design of fish passage enhancement structures at and adjacent to the Winnicut Dam. Unlike the peak flow hydrologic analysis performed above, the purpose of this analysis was to determine a *range* of anticipated flows during target fish migration windows.

The hydrologic analysis was performed for smelt and river herring only. American eel were not considered in this analysis due to their ability to migrate upstream beyond structures such as dams.

Target fish migration windows were established based upon consultation with NHFGD fisheries personnel (Table 4).

Table 4: Target Fish Migration Windows

Fish Species	**Migration Window**
Rainbow Smelt	March 15 – May 7
River Herring	April 15 – June 30

Flows during the target fish migration windows were evaluated using historical flow data obtained from USGS Station 01073785 on the Winnicut River and from USGS Station 01073000 on the nearby Oyster River near Durham, New Hampshire (Figure 7). Data was used because the data record for this gage is substantially greater than the data record for the Winnicut River gage station (67 years versus 2 years) and consequently provides a more accurate determination of flows during the target fish migration windows.

Measurement of flow speeds in Winnicut River under Rte 33 Bridge during drawdown – October 2003

The development of flow statistics for the Winnicut River from data obtained on the Winnicut River was initiated with a paired comparison of average daily flow records from 9 July 2002 through 25 August 25 2003, a period of 413 days during which the two USGS gages were in simultaneous operation. A total of 347 paired data records were incorporated into this analysis, with 66 days excluded from the analysis because data was not available from one or both of the gages.

The comparison of the paired data was performed using a linear regression analysis of unit flows (i.e., total flow divided by drainage area), with the Oyster River and Winnicut River data representing the independent and dependent variables for this analysis, respectively. The regression analysis yielded a slope of 0.945, a y-intercept of 0.380, and a correlation coefficient of 0.936. The skew of this slope predicts higher peak flows for the smaller watershed (Oyster River) and greater base flow for the larger watershed (Winnicut River), results that are consistent with regional hydrologic conditions.

Based on the comparison of the paired data, it was determined that a sufficient correlation existed between the daily flow characteristics on the Oyster and Winnicut Rivers to generate flow statistics for the target fish migration windows using 67 years of daily flow data obtained from the USGS Gage on the Oyster River. Flow statistics for the smelt and river herring migration windows were developed by transforming the Oyster River daily flow data using the results of the regression analysis and ranking the flow data for each of the respective migration windows to produce flow duration curves for the target fish migration windows. The results of this analysis are presented in Table 5 and shown graphically in Figure 8.

Table 5: Target Fish Migration Window Flow-Duration Statistics

Exceedence Percentile	**Flow (cfs)**	
	Rainbow Smelt	**River Herring**
20%	82	43
50%	46	23
80%	29	12

Note: The exceedence percentile represents the percent of time when the daily flow exceeds the stated value.

The design criteria for the evaluation of conceptual fishpass facilities as part of the Feasibility Study was the mean flow (50^{th} percentile) for the target species migration window. A final design should incorporate fishpass performance at higher and lower flows. Note that traditional technical fishpass structures (e.g., Denil, Alaska Steeppass) must be adapted to a range of flow conditions by controlling the fraction of the total riverine flow through the technical fishpass.

3.3.3 Hydraulics in the Vicinity of the Winnicut Dam

Existing and proposed hydraulic conditions in the vicinity of the Winnicut Dam were evaluated using a variety of qualitative and quantitative methodologies as part of the Feasibility Study, as it was determined that no single methodology was applicable to all of the tasks requiring analysis. The specific methodologies, selected based on their ability to provide the required level of resolution for specific tasks, ranged from qualitative observations to complex quantitative methods, such as three-dimensional computational fluid dynamics (CFD) models that were used to evaluate hydraulic conditions under the Rte 33 Bridge and sediment trapping in the impoundment upstream of the bridge. These methodologies are further described in the following sections.

Backwater Conditions Caused by the Winnicut Dam and the Rte 33 Bridge

The extent of the backwater on the Winnicut River created by the Winnicut Dam was determined based on qualitative observations of flows and geomorphic features along the reach of river upstream from the dam. This information was augmented with information obtained from quantitative hydraulic analysis performed to evaluate hydraulic conditions at the Winnicut Dam and at the Rte 33 Bridge.

The importance of the backwater is that it represents the upstream extent of the impact Winnicut Dam on water levels in the Winnicut River. Upstream of the backwater, any changes to the configuration or operation of the Winnicut Dam would not have an effect on hydraulic conditions, such as water levels, in the Winnicut River. To some extent, this also represents the limit of effects on groundwater adjacent to the Winnicut River resulting from the configuration and operation of the Winnicut Dam.

The maximum observed extent of the backwater occurred on March 22, 2003, when a flow of approximately 140 cfs was recorded at the USGS gaging station located at the Winnicut Dam (a volume of flow that can be considered to be slightly less than the typical annual maximum flow for this reach of the Winnicut River). The backwater at this time appeared to extend approximately 7,000 feet upstream of the dam at a location approximately 500 feet downstream of what appears to be an old dam and/or road crossing. The backwater typical of summer flows of less than 10 cfs appeared to extend approximately 6,300 feet upstream of the Winnicut Dam.

The quantitative hydraulic analyses developed for the bridge scour study (Section 0) also provided insight into the causes and extent of the backwater effects created by the Winnicut Dam and the Rte 33 Bridge. Data from this analysis indicate that during periods of high flows associated with hydrologic events with return intervals of between 25 and 100 years (probabilities of occurrence of 0.04 and 0.01, respectively), the backwater created by the Rte 33 Bridge controls water levels upstream of the bridge. Under these conditions, the configuration and operation of the Winnicut Dam has no effect on the upstream water levels.

Based on the aforementioned information, the current configuration and operation of the Winnicut Dam has no effect on water levels in the Winnicut River upstream of a location approximately 7,500 feet upstream of the dam (Figure 9).

Hydraulic Conditions Associated with Bridge Scour at the Rte 33 Bridge

Hydraulic conditions in the vicinity of the Winnicut Dam and the Rte 33 Bridge were evaluated to develop information for a bridge scour study for the bridge for existing conditions (Dam In) and for a scenario based on the removal of the Winnicut Dam with no changes to the stream channel upstream of the dam (Dam Out). The bridge scour analysis was performed in accordance with methodologies presented in Federal Highway Administration Hydraulic Engineering Circular No. 18, "*Evaluating Scour at Bridges, 4th Edition*" (HEC-18). The hydraulic analysis for the bridge scour analysis was performed using the one-dimensional US Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) numerical hydraulic model (HEC-RAS model). This model was selected for use in the bridge scour study as it readily provides the necessary hydraulic parameters and is widely used and accepted for this type of study.

Hydrology

The bridge scour study was performed using peak flow data developed in Section 3.3.2 for hydrologic events with return intervals of 10, 25, 50, 100, and 500 years. Geometric data (i.e., cross-section geometry and locations) for the bridge scour study was obtained from the bathymetric and topographic surveys performed as part of the Feasibility Study.

Model Geometry

Cross-sections for the HEC-RAS model were created from a digital terrain model developed from topographic and bathymetric surveys performed as part of the Feasibility Study. The cross-sections were located as specified in HEC-18 along a reach of the Winnicut River beginning approximately 80 feet downstream of the Winnicut Dam and ending approximately 90 feet upstream of the Rte 33 Bridge, for a total reach length of 520 feet. Two model geometries were developed for the bridge scour study: Dam In and Dam Out. Geometric data for the Winnicut Dam was obtained from the plans for the dam and from the dedicated site survey (Appendix 6). To enhance the resolution of the model and better resolve the location and magnitude of calculated hydraulic jumps, interpolated cross-sections were created at a maximum interval of 10 feet for the modeled geometries.

While a model geometry was also developed incorporating the special bridge routines in HEC-RAS, the constriction in the Winnicut River under the Rte 33 Bridge was ultimately modeled without these routines. This decision was made based on the severity of the contraction and the determination that a more accurate analysis of hydraulic conditions could be obtained by using additional cross-sections under the bridge so as to better represent the channel geometry. Energy losses entering and exiting the contracted reach under the bridge were accounted for by increasing the contraction and expansion coefficients in the immediate vicinity of the Rte 33 Bridge. While a comparison of water surface profiles calculated using this methodology with water surface profiles calculated using the special bridge routines for Dam Out conditions showed little difference in the calculated water levels upstream of the bridge, the selected approach did not exhibit what appeared to be physically implausible behavior under the bridge that were apparent with the use of the special bridge routines.

Boundary Conditions

Downstream boundary conditions for the HEC-RAS analyses were applied using normal depth calculations and a representative downstream channel slope. To determine whether tidal influences would impact flow conditions under the Rte 33 Bridge, calculations were also performed using the Dam Out geometry and a downstream boundary condition based on the peak tidal surge water surface elevation for a 100-year event, as presented on the applicable Federal Emergency Management Flood Insurance Study for Greenland, New Hampshire. This analysis indicated that supercritical flow would persist under the Rte 33 Bridge for all of the events analyzed. Therefore, all of the HEC-RAS analyses used for the bridge scour study were performed assuming steady-state calculations.

Hydraulic Conditions Pertinent to Fish Passage at the Rte 33 Bridge

A hydraulic analysis was performed to assess the potential for fish passage in the vicinity of the Winnicut Dam and the Rte 33 Bridge for the conceptual and primary alternatives. This dedicated analysis was undertaken after observed bathymetric conditions and preliminary hydraulic analyses suggested that target fish species might not be capable of ascending the constricted reach of the Winnicut River in the immediate vicinity of the Rte 33 Bridge. Pertinent information on swimming speeds of the target fish species is presented in Appendix 7 of this report.

Model Setup

Because of inherent limitations on the resolution of typical numerical hydraulic modeling software relative to the evaluation of upstream fish passage, a specialized three-dimensional, free-surface, numerical modeling program was used to calculate flow conditions for the analysis of fish passage (Figure 10). As input, this computer program requires topographic data and specified flows. As output, this computer program provides estimates of three-dimensional velocities and water surface elevations throughout the modeled river reach. The results of these computer simulations were subsequently compared to swimming speeds of target fish species to assist in the development of alternatives intended to achieve the project goals associated with upstream fish passage.

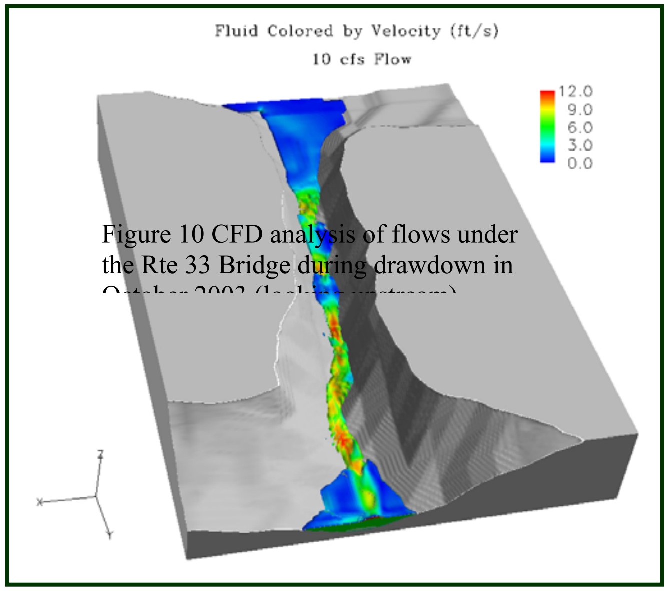

Figure 10: CFD analysis of flows under the Rte 33 Bridge during drawdown in October 2003 (looking upstream)

Hydrology

Flows for this analysis were determined using information developed in Section 3.3.2 of this study, and were set at 40 cfs for the evaluation of potential fish passage in this study. This value represents the 50th percentile (i.e., average) flow during the smelt migration window and the 25th percentile flow during the river herring migration window. Analyses performed using this flow provide a general estimate of whether the weak-swimming smelt might ascend through the modeled reach during average conditions and whether the strong-swimming river herring might ascend through the modeled reach at the limit of the upper quartile of the anticipated flow regime.

Winnicut River under Rte 33 Bridge during drawdown – October 2003

Analysis

Three preliminary simulations were performed to estimate general hydraulic conditions associated with existing conditions and post-dam removal in the vicinity of the Winnicut Dam and the Rte 33 Bridge. The results of the existing conditions simulation indicate that the target fish species are likely capable of ascending the Winnicut River under the Rte 33 Bridge during the calculated range of expected flows during the migration window. The results of the analysis simulating conditions resulting from the removal of the Winnicut Dam indicate that the target fish species would not be capable of ascending the Winnicut River under the Rte 33 Bridge during the calculated migration window flows. Based on this finding, it was determined that alternatives incorporating the removal of the Winnicut Dam would necessitate the development of remedial measures to improve upstream fish passage at the Rte 33 Bridge.

In response to the determination that the target fish species would not be capable of ascending the Winnicut River under the Rte 33 Bridge during the calculated migration window flows, hydraulic conditions associated with a conceptual technical fishpass situated between the Winnicut Dam and the Rte 33 Bridge were analyzed. While this conceptual alternative was not developed further, it provided insight for the development of other means to achieve upstream fish passage upstream of the Rte 33 Bridge.

The results of these preliminary analyses suggested that the project goals could be achieved through the removal of the Winnicut Dam and the development of alternatives capable of providing diadromous fish access to the Winnicut River upstream of the Rte 33 Bridge. Information obtained in these preliminary analyses was subsequently used in the development of the primary alternatives.

Two additional simulations were performed following the drawdown of the impoundment upstream of the Winnicut Dam in October 2003. The purpose of these simulations was to evaluate hydraulic conditions associated with upstream fish passage under the Rte 33 Bridge for the existing bathymetric conditions under the bridge and to provide information for the development of a primary alternative incorporating the removal of the Winnicut Dam and the construction of a technical fishpass under the Rte 33 Bridge.

In the first simulation, the simulated flow rate under the Route 33 Bridge was set to 10 cfs, as observed in the river on 17 October 2003 during the drawdown of the impoundment upstream of the Winnicut Dam. Measurements of current speed and water surface elevation made at this time in the river were used to calibrate this simulation. In the second simulation, the simulated flow rate under the Route 33 Bridge was set to 40 cfs to evaluate conditions during the target anadromous fish migration window. This simulation confirmed a prior hypothesis that the target anadromous fish would not be able to ascend the Winnicut River beneath the Rte 33 Bridge if the Winnicut Dam were removed and no changes were made to the existing bathymetry under the bridge.

Parameter values determined in the model calibration simulation (i.e., the 10 cfs simulation) and the 40 cfs simulation were subsequently used to make judgments in the design of a technical fish pass beneath the Route 33 Bridge as incorporated into Alternative C.

3.3.4 Flooding

Peak flooding condition adjacent to the Winnicut Dam were determined using base flood elevation data presented on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) developed for the town of Greenland, New Hampshire (FEMA Community No.: 330210)[5]. This map was prepared using information presented in the FEMA Flood Insurance Study (FIS) for Greenland, which has an effective date of 17 May 1989. While the FIS evaluated flooding for a range of return-interval hydrologic events, further discussion in this Feasibility Study will be limited to the base flood elevations as calculated for a 100-year return-interval event.

The base flood elevation downstream of the Winnicut Dam results from tidal effects, and is specified as 7 feet NGVD-29[6] (6 feet NAVD-88[7]). Because the existing spillway elevation of the Winnicut Dam is approximately 11 feet NAVD-88, or 5-feet higher than the predicted base flood elevation, these tidal effects would not propagate upstream of the dam in the event of the predicted flood magnitude. If the Winnicut Dam were removed, the predicted flood stage resulting from tidal effects would propagate upstream to the Rte 33 Bridge. Because the calculated peak flood elevation is 4 feet lower than the normal impoundment water surface elevation with the dam in place, however, the removal of the dam would not increase the associated flood risk due to tidal effects upstream of the dam.

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[5] The FIRM covering the project area is Community-Panel No.: 330210 0002 B.

[6] National Geodetic Vertical Datum of 1929 (NGVD-29)

[7] North American Vertical Datum of 1988 (NAVD-88). The relation between NGVD-29 and NAVD-88 at this site is: elev (NGVD-29 [feet]) – elev (NAVD-88 [feet]) = 0.751 (feet), based on NGS PID #. OC0405.

Base flood elevations upstream of the Rte 33 Bridge have not been calculated by detailed methods. Consequently, the extent of the 100-year floodplain, as shown on the FIRM maps, are approximate (Appendix 8).

3.3.5 Sediments

Surficial sediment samples were collected at four locations within the Winnicut River in the vicinity of the Winnicut Dam (Figure 13). The primary purpose of the sampling was to provide sediment for the analytical analysis of potential contaminants. Information on the representative size fractions of the surficial sediments in the Winnicut River was also obtained using these samples.

Sediments in the impoundment upstream of the Winnicut Dam during drawdown – October 2003

Sediment samples were obtained using a Petit Ponar sampler and a hand corer, as necessary.

Sediment Size Analysis

The average sediment particle size by weight (D_{50}) of the two sample sediment samples obtained from the impoundment upstream of the Winnicut Dam varied substantially from information on native soils in the vicinity of the bridge that were obtained from soil borings prior to the construction of the bridge. The D_{50} of the surficial sediments obtained for this study was less than 1.0 mm, while the soil boring data reports a Unified Soil Classification System designation of "silty gravel" below the surficial streambed sediments. This classification indicates that the D_{50} of the material was greater than 6.75 mm, and could be as large as 64 mm. This difference likely results from the material used in the 2003 analyses having been obtained from immediately below the existing streambed while the material obtained from the historic borings was obtained from strata well below the streambed. In other words, the material collected for this study was most likely deposited since the construction of the Winnicut Dam and the Rte 33 Bridge while the material collected during previous work was of older alluvial deposits characteristic of the riverbed conditions at that time.

Sediment Volume

The volume of sediment deposits in the Winnicut River between the Winnicut Dam and the Rte 33 Bridge was calculated by approximate methods to provide information for the evaluation of the proposed alternatives. This evaluation was limited to the reach of the river between the dam and the bridge, as this is the only area where implementation of a primary alternative action would result in long-term changes in water surface elevations relative to existing conditions.

The approximate volume of sediments was calculated using terrain and bathymetric data collected as part of this study, as well as observations made during the drawdown of the impoundment in October 2003. These observations were used to determine a conceptual, post dam-removal channel geometry, based upon observed sediment deposits and adjacent channel geometries. The approximate volume of sediment was subsequently calculated using a quantitative analysis of a terrain model representative of the existing terrain in the vicinity of the dam with a conceptual terrain model developed based on conditions observed during the drawdown.

The calculated volume of sediments using this method is approximately 1,500 cubic yards (CY). This estimate includes sediments and soils that would likely require excavation and removal as part of the spillway and right (east) abutment of the Winnicut Dam, but does not include any excavation of fill adjacent to the dam abutments or apron during removal of the dam. A similar analysis was also performed in which the excavation of soils at the east abutment, sediments under the apron, and sediments that would likely need to be excavated adjacent to the upstream face of the dam as part of dam removal, were excluded (Figure 11). This analysis results in volume of sediments of approximately 1,000 CY within the impoundment between the dam and Rte 33 Bridge. This volume of material represents a likely upper threshold of sediments that might be eroded from the impoundment between the Winnicut Dam and the Rte 33 Bridge and transported downstream due to the removal of the Winnicut Dam.

Sediment Transport

Eroding bank along Winnicut River upstream of YMCA Camp Gundalow – April 2003

An assessment of sediment transport in the reach of the Winnicut River impounded by the Winnicut Dam was performed to provide information for the evaluation of the primary alternatives. This assessment evaluated factors associated with sediment transport and deposition in the vicinity of the Winnicut Dam. Both a qualitative assessment based on observed characteristics associated with sediment, morphologic, and hydraulic conditions in the Winnicut River and a quantitative analysis of sediment transport incorporating theoretical and empirical sediment transport methodologies were incorporated.

At the inception of this study, it was proposed that sediment transport in the Winnicut River be evaluated using the USACE's SAM Hydraulic Design Package software system (SAM). The sediment transport methodologies in SAM are applicable to screening-level assessments of sediment transport and can provide information at specific stream channel cross-sections within the target riverine system. SAM is not applicable to the analysis of a reach of river, however, except as it might be represented by an average of stream channel cross-sections and hydraulic parameters through the reach.

Sediments in impoundment upstream of the Winnicut Dam – October 2003

The relatively small volume of accumulated sediments between the Winnicut Dam and the Rte 33 Bridge can be explained based on the information presented in the previous paragraphs and from the results of the sediment size analyses performed as part of the Feasibility Study. The results of this analysis indicate that the characteristic size of the surficial sediments is small, with an average size of less than 1 mm. A fundamental characteristic of this size sediment is that they tend to be transported over a broader range of flow speeds. An apparent consequence of this condition is that fine sediments transported into the impounded reach of the Winnicut River upstream of the Winnicut Dam and the Rte 33 Bridge are either trapped in the impoundment upstream of the bridge or are transported downstream of the dam.

Sediment Transport in Impoundment Upstream of the Rte 33 Bridge

To test the hypothesis that fine sediments would be transported through the impoundment upstream of the Rte 33 Bridge, a three-dimensional numerical hydraulic modeling program was implemented.

Sediment transport and trapping was evaluated for five sediment sizes as part of the analysis, including the average sediment size of the sediment samples obtained from the impoundment as part of this study (0.12 mm). Sediment parameters and the results of the sediment trapping analysis are presented in Table 6.

Table 6: Sediment Trapping Analysis

Description	Diameter (mm)	Fall Velocity (ft/sec)	Trapping Efficiency / Return Interval Event		
			2-year	10-year	100-year
Fine gravel	5.0	0.479	100%	100%	100%
Coarse Sand	1.0	0.169	100%	100%	100%
*Very Fine Sand**	0.12	.011	100%	100%	100 %
Fine Silt	0.01	.00009	25%	12%	6%
Very Fine Silt	0.005	.00002	7%	3%	3%

*Dominant material in surficial sediments determined from sieve analysis for this study.

Note: Fall velocity is the terminal velocity of a sediment particle in water based on a water temperature of 65 degrees F, specific gravity of 2.65, and a shape factor of 1.0.

The results of this analysis confirm the hypothesis that the impoundment upstream of the Rte 33 Bridge functions as a sediment trap for larger sediments and that smaller sediments are transported through the impoundment.

Sediment Transport Between the Rte 33 Bridge and Winnicut Dam

Sediment transport in the Winnicut River between the Rte 33 Bridge and Winnicut Dam was evaluated qualitatively to provide an estimated volume of material that might erode if the Winnicut Dam were removed. This evaluation was performed based on observations during a variety of flow regimes, including the October 2003 drawdown of the impoundment upstream of the dam, and the previously discussed quantitative analysis of sediment transport in the impoundment upstream of the Rte 33 Bridge.

Sediments upstream of Winnicut Dam – October 2003

The morphology of the impoundment between the Winnicut Dam and the Rte 33 Bridge is defined by a channel with an armored bottom on the left (west) and sediment deposits on the right (east). This morphology is consistent with the dominant flow pattern in the impoundment, which is characterized by a strong current flowing through the left side of the impoundment from the channel under the Rte 33 Bridge and an eddy flowing upstream on the right (Figure 12). The apparent consequence of this flow pattern is that sediments and detritus flowing into the impoundment are conveyed downstream and over the dam during periods of high flows, and enter the back-eddy on the right and circulate within the system during periods of lower flows.

Observations of sediment deposits in the impoundment during the October 2003 drawdown indicate the presence of some sandy and silty material in addition to a large amount of organic material, including terrestrial and aquatic plant detritus. With the exception of some sandy material located to the right of the channel downstream of the Rte 33 Bridge, this material does not appear to be consolidated.

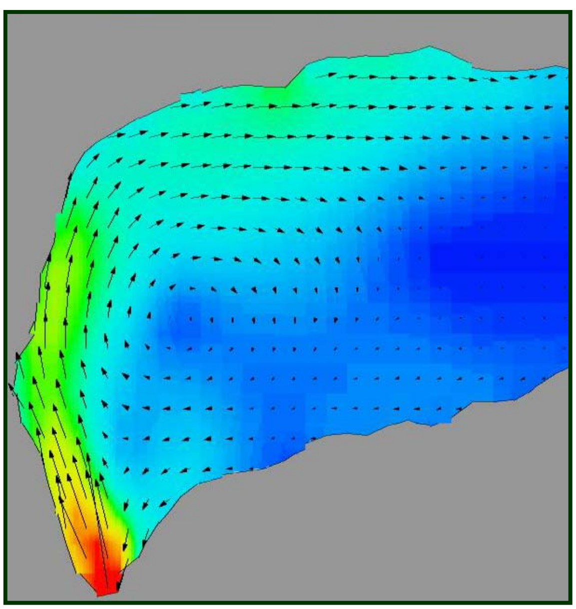

Figure 12: Calculated flow patterns at 40 cfs between Rte 33 Bridge with dam removed. Red and yellow represent areas of higher speeds while blue represents lower speeds.

If the Winnicut Dam were removed, the main channel would likely remain along the left bank immediately downstream of the Rte 33 Bridge. No sediment deposits were observed in this area, and significant erosion of the native substrate during the typical annual flow regime is not likely due to the presence of an armor layer that likely formed during the period following the failure of the timber crib dam at the present dam site in 1941. In addition, what appears to be a gravel bar or the remains of a cofferdam approximately 100 feet downstream of the old bridge abutments may act as a grade control structure within the channel and therefore limit the erosion of the native sediments. During flood events, it is possible that natural channel formation processes could affect the geometry of the channel in this area. These changes would be consistent with natural channel formation processes, however, and do not warrant evaluation in within the context of dam removal.

Gravel bar or crib dam in channel between Winnicut Dam and Rte 33 Bridge – October 2003

The erosion and transport of sediments on the right side of the impoundment between the Winnicut Dam and the Rte 33 Bridge following dam removal would depend upon factors, including whether the entire dam or just the spillway is removed, tidal conditions during a given flood event, and the length of time between the removal of the dam and later flood events. If only the spillway section of the dam were removed, the presence of the left (west) abutment and existing fish ladder would force flows towards the right side of the channel into existing sediment deposits. If peak flows associated with a given flood event occur during high tide, the tidal backwater will tend to reduce velocities and inhibit erosion on the right side of the channel, and therefore limit erosion of sediments. If there is a gap of a few years following the removal of the dam before a large flood occurs, the growth of new vegetation on top of the sediments would tend to reduce the erosion and transport of sediments.

Based on the aforementioned factors, it is not possible to determine the precise volume of sediments that might be transported downstream if the Winnicut Dam were removed. The likely maximum volume of sediments that might be eroded is the total volume of accumulated sediments in the area between the dam and the Rte 33 Bridge, or 1,500 CY. A preliminary calculation indicated that approximately 500 CY of material would need to be excavated during the removal of the dam, resulting in a net volume of material susceptible to erosion of 1,000 CY. This value (1,000 CY) should

Sediment sampling location downstream of Winnicut Dam – September 2003 therefore be considered the upper threshold of the volume of material that might be eroded and transported downstream as the result of dam removal. Note that a large portion of this material appears to be organic detritus that would tend to be transported well downstream during flood events. Overall, there does not appear to be a sufficient volume of material to affect the morphology of the Winnicut River downstream of the Winnicut Dam.

Sediment Sampling and Constituent Analyses

Sediment constituent analyses were performed for sediment samples collected within the Winnicut River (Figure 13). Analytical testing of sediments was in accordance with the NHDES memo titled "Evaluation of Sediment Quality by Chemical Analysis for Dam Removals" and NHDES-R-WD-02-***9***, "Evaluation of Sediment Quality." The purpose of the sediment sampling is to provide screening-level data on potential contamination of sediments within the Winnicut River adjacent to the Winnicut Dam.

Analytical Constituent Analyses

The analytical constituent analyses were performed by Katahdin Analytical Services, Inc. (NH #2001). The sediment samples were analyzed for the following physical and chemical parameters using the specified methodologies:

a) Total organic carbon;
b) Grain size distribution via sieve and hydrometer by American Society for Testing and Materials (ASTM) Method D-422, or a comparable method;
c) Polynuclear aromatic hydrocarbons (PAHs) by US Environmental Protection Agency (USEPA) Method 8270C;
d) Polychlorinated biphenyls (PCBs) by USEPA Method 8082;
e) Pesticides by USEPA Method 8081;
f) Selected metals (arsenic, barium, cadmium, chromium (total), copper, lead, mercury, nickel, zinc by USEPA Methods 6010 and 7174 (mercury only);
g) VOCs by USEPA Method 8260B; and
h) SVOCs by USEPA Method 8270C.

Results of Sediment Constituent Analyses

All of the results of the sediment constituent analyses are presented in Appendix 9. The results of the sediment constituent analyses for metals are presented in Table 7, and indicate that the concentrations are above the Threshold Effects Level (TEL). The results of the sediment constituent analyses suggest that the evaluated constituents are distributed uniformly within the reach of the River sampled and are not concentrated within the area impounded specifically by the Winnicut Dam. This condition is consistent with a dispersed source of constituents, such as atmospheric deposition, and is not indicative of point source discharges within the studied reach of the river.

Table 7: Results of Sediment Analyses for Metals

	TEL		TEC	Probable Effects Level		IMP#1	IMP#2	DS#1	US#1
	SQuiRT TEL (ppb)	SQuiRT TEL (ppm)	USEPA (1977) TEC (ppm)	SQuiRT PEL (ppb)	SQuiRT PEL (ppm)	*ppm*	*ppm*	*ppm*	*ppm*
ARSENIC	5,900	5.90		17,000	17.00	**13.9**	**12**	**12**	**14.2**
BARIUM			20.00			**63.5**	**52.8**	**29.4**	**63.4**
CADMIUM	596	0.60		3,530	3.5	**1.06**	**1.75**	**1.6**	**1.41**
CHROMIUM	37,300	37.30		90,000	90.0	**38.1**	**39.6**	**61**	31.8
COPPER	35,700	35.70		197,000	197.0	13.8	10	16.8	7.5
LEAD	35,000	35.00		91,300	91.3	23.8	15	23.6	12
MERCURY	174	0.174		486	0.5	0.086	0.044	0.11	0.054
NICKEL	18,000	18.00		35,900	35.9	**31.1**	**26.4**	**27.8**	**19.2**
ZINC	123,100	123.10		315,000	315.0	72.4	79.6	70	59.1

BOLD values indicate exceedence of Threshold Effects Level (TEL) or Threshold Effects Concentration (TEC)

3.3.6 Ice Jamming

A dedicated evaluation of potential ice jams resulting from the removal of the Winnicut Dam was not performed as part of this feasibility study. However, a letter to the NHDES from the US Army Cold Regions Research and Engineering Laboratory (CRREL) dated 17 September 2002 presents observations and recommendations pertinent to ice jamming on the Winnicut River (Appendix 10). This letter states that the CRREL Ice Jam Database contained no records of ice jams in the Winnicut River, but notes records of ice jams on the Lamprey River in Newmarket, New Hampshire. The letter states that because the dam is located at the head-of-tide, removal of the dam could result in "freezeup jam formation" at or near the head-of-tide if the dam were removed.

Ice on the Winnicut River downstream of the Winnicut Dam – March 2003

3.4 GROUNDWATER RESOURCES

A qualitative analysis was performed to evaluate impacts to groundwater resources in the Winnicut River watershed resulting from the modification or removal of the Winnicut Dam and associated effects on upstream water levels. This assessment was performed through the evaluation of a gross water budget quantifying the volume of water entering, leaving and stored in the watershed.

3.4.1 Groundwater Resources in the Winnicut River Watershed

The Winnicut River watershed encompasses approximately 14.2 square miles and receives approximately 49 inches of precipitation each year. Twenty-nine inches of this annual precipitation is lost to the atmosphere from the watershed through evapotranspiration, which is a combination of direct evaporation and moisture that is transpired into the atmosphere through plant leaves. Therefore, approximately 20 inches of precipitation either infiltrates into the ground or flows overland into the Winnicut River or its tributaries. Assuming the watershed has no net annual change in storage, the amount of water entering and leaving the surface water/groundwater system of the Winnicut River watershed is approximately 15,000 acre-feet[8] per year.

The Winnicut Dam impounds approximately 4.1 acre-feet between the dam and the Route 33 Bridge and approximately 30 acre-feet in the impoundment immediately upstream of the bridge when the water level is at the top of the dam spillway, for a total impounded volume of approximately 34.1 acre-feet (11.1 million gallons).

While dams can increase the total volume of water stored in a watershed, they do not increase or decrease the total volume of water passing though the watershed. Although this additional water can provide benefits such as flood storage and providing a relatively constant source despite seasonal variations in water demand and water recharge, it can also result in increased losses of water due to evaporation. A typical benefit associated with the storage of water results from the availability of impounded water in summer and early fall when water demand is typically at its annual maximum and recharge to aquifers and streams is at its annual minimum. Therefore, water that might otherwise by withdrawn from aquifer storage (i.e., groundwater) can be obtained from impoundments during this period to make up for the recharge deficit.

To assess the affects of removing the Winnicut dam to storage in the Winnicut River watershed, an estimate of the watershed's storage capacity was evaluated. Groundwater in the New Hampshire Seacoast region is stored in two basic geologic units; 1) overburden, and 2) bedrock. The overburden consists of the sands, gravels and soils that overlie the bedrock. For the purposes

[8] One acre-foot equals the volume of water covering one acre, one foot deep

of this estimate, it was conservatively assumed that no water is stored in the overburden materials.

To estimate the amount of water stored in the bedrock, it was assumed that this water is available to a depth of 300 feet, which is the average depth of bedrock wells in Seacoast New Hampshire. Water is stored in bedrock in cracks and fissures that constitute on average 2 percent of bedrock volume. Therefore the amount of water stored in bedrock in the Winnicut River watershed is estimated to be 54,528 acre-feet or 18 billion gallons. The amount of water stored behind the Winnicut dam, 11.1 million gallons, therefore represents 0.06 percent of the total storage available in the bedrock aquifer of the Winnicut River watershed. Therefore, removal of the Winnicut dam would likely have no measurable affect on the amount of water available to bedrock well users in the Winnicut River watershed.

3.4.2 Groundwater Resources and Water Wells in the Vicinity of the Winnicut Dam

Removal of the Winnicut Dam would have the greatest impact on dug (overburden) water well users located within several hundred feet of the Winnicut River upstream of the dam. As incorporated into Alternative C, removal of the Winnicut Dam would result in a decrease in normal water levels in the impoundment immediately upstream of the Rte 33 Bridge of 1 to 2 feet. This would result in a proportional drawdown in the overburden groundwater table adjacent to wells located next to the impoundment and a lesser drawdown in wells located further away. Dug wells are becoming very uncommon and to date the well water survey has not indicated the presence of any dug well users among Winnicut River abutters.

In conclusion, the removal of the Winnicut Dam would have negligible impacts to bedrock well users in the vicinity of the Winnicut River and elsewhere. The storage afforded by the dam is very small compared to that of the watershed as a whole. In addition, as stated on page 8 of a June 30, 1999 report titled *"Water Resources Evaluation - Winnicut River Watershed Study,"*

> *Intermediate and deep fracture zones are not typically well connected (hydraulically) with overlying overburden due the presence of competent bedrock below shallow fracture zones. Water in deep fractures zones in lowland areas is typically recharged on a regional basis miles away. Water in these regional fracture zones does not generally discharge locally to overburden or surface water bodies; it flows 'beneath' the watershed and discharges to areas outside the watershed. In the case of the Winnicut River watershed, intermediate and deep bedrock fracture zones are likely recharged from inland areas miles west of*

the watershed and discharge to the Atlantic Ocean east of the watershed. Accordingly, extracting water from these fracture zones would not likely result in significant changes in overburden groundwater levels or the amount of water discharging to surface water bodies in the watershed as base flow.

By the same reasoning used in the previous sentence, reducing the surface water elevation of the Winnicut would not likely result in changes to water available in bedrock fracture zones.

The extent of a drawdown in the overburden groundwater table resulting from a permanent lowering of water levels in the Winnicut River would be a function of the magnitude, or height, of the drawdown and the distance from the edge of the river. Immediately upstream of the Rte 33 Bridge, the maximum extent of the drawdown would be between 1 and 2 feet at the edge of the river, with the drawdown diminishing further from the river. The rate at which the drawdown diminishes from the river would be, to a large extent, a function of the subsurface soil properties. Porous soils, such as sands and gravels, would result in a larger area of drawdown, while less porous soils would tend to limit the overall extent of a drawdown. Water levels in overburden wells would experience effects similar to those experienced in the adjacent overburden groundwater table, with a maximum drawdown of 1 to 2 feet for a well immediately adjacent to the river, with smaller drawdowns experienced by wells further away from the river. Potential effects to the overburden groundwater table from the implementation of the primary alternatives would be minimal upstream of the YMCA's Camp Gundalow.

No functioning overburden wells were located in the area between the Winnicut Dam and the Rte 33 Bridge where the potential removal of the dam would result in a surface water drawdown of approximately 10 feet.

3.5 INFRASTRUCTURE

3.5.1 Rte 33 Bridge

The Rte 33 Bridge is situated approximately 250 feet upstream of the Winnicut Dam, and was constructed in 1959, two years after the construction of the Winnicut Dam. This bridge was placed immediately upstream of an earlier bridge, the masonry abutments of which sit north of the current bridge and are visible from the land abutting the Winnicut dam. The construction of the 1959 bridge resulted in the filling of approximately 14,000 square feet of the Winnicut River and the raising of the stream bottom under the bridge by approximately 8 feet.

Bridge Scour Analysis

A bridge scour study was performed as part of the Feasibility Study to assess potential impacts associated with the project alternatives on the Rte 33 Bridge. This study evaluated scour based for existing conditions (Dam In) and for a scenario based on the removal of the Winnicut Dam with no changes to the stream channel upstream of the dam (Dam Out). The bridge scour analysis was performed in accordance with methodologies presented in HEC-18. The development of hydraulic and geometric parameters for the bridge scour study is presented in Section 3.3.2 . Additional information on the bridge scour analysis is presented in Appendix 11.

Sediment Size Data

Sediment size data used for the bridge scour study was obtained from soil boring data shown on the plans for the Rte 33 Bridge. The soil borings were obtained in February of 1959 prior to the construction of the bridge. While soil gradation analyses were performed on surficial sediment samples obtained upstream and downstream of the bridge as part of the Feasibility Study, it was determined that this data is not representative of conditions associated with bridge scour at the Rte 33 Bridge.

The determination to use the soil boring data for the bridge scour study was made based on the apparent difference in sediment sizes obtained from the soil boring data and the gradation analyses and the determination that the soil boring data is more representative of conditions pertinent to the evaluation of bridge scour. While the soil boring data indicates that the subsurface material is a silty gravel (6.75 mm < D_{50} < 64 mm) the average sediment particle size by weight (D_{50}) as determined from the gradation and hydrometer analyses of the two sample sediment samples obtained in the immediate vicinity of the Rte 33 Bridge was less than 1 mm. Based on this information, the scour analysis was performed using a "representative" D_{50} of 10 mm. Note that the selection of the representative particle size will affect the calculated scour depths, but will not affect the difference between the calculated scour depths for the two cases evaluated here.

The apparent difference in sediment sizes can be reconciled based on the different methods by which the samples were obtained. While the soil boring samples were obtained from strata well below the streambed at the time of sampling, the sediment samples used in the sediment size analyses performed as part of the Feasibility Study were obtained from surficial deposits immediately below the current streambed. It is most likely that the material represents superficial sediments than have deposited since the construction of the Winnicut Dam and the Rte 33 Bridge, and therefore, that these sediments are not representative of underlying, native materials.

Bridge Scour Calculations

Potential scour at the Rte 33 Bridge was evaluated using general and local scour equations as presented in HEC-18. General scour was evaluated based on contraction scour only, as sufficient data for evaluating long-term scour was not available. Local scour was calculated based on abutment scour only, as the Rte 33 Bridge is a single span structure without supporting piers. Abutment scour was calculated using the Froelich equation, as criteria for the application of the HIRE equation were not met. Total scour was calculated as the sum of general and local scour.

A structural stability analysis was not performed as part of this study, and the calculated scour depths and extents were not plotted.

Results and Discussion

The results of the bridge scour study are presented in Table 8, and indicate the potential for bridge scour at the Rte 33 Bridge. The calculated results are consistent with the observed and calculated hydraulic conditions, as the geometry of the bridge approach embankments and the narrow channel under the bridge results in constricted flows, a condition that often increases both calculated and actual scour depths. That a large difference in the calculated depths of scour was not obtained for the Dam In and Dam Out scenarios is consistent with the scour methodologies in HEC-18, as these methods rely heavily on hydraulic conditions upstream of a bridge, and these conditions do not substantially vary for the evaluated scenarios.

That the calculated depths of scour have apparently not occurred at the bridge is not unexpected, based upon the methodologies and assumptions used in the development of the bridge scour equations presented in HEC-18. To a large extent, the applied methodology is based on laboratory studies and does not account for all of the factors pertinent to actual scour or the presence of the existing scour countermeasures at the Rte 33 Bridge.

If the Winnicut Dam were removed, it would likely result in an increased rate of deterioration of the existing scour countermeasures at the Rte 33 Bridge, as loose rock at the downstream end of the channel under the bridge would be subjected to increased hydrodynamic forces and swept downstream. The dewatering of the impoundment downstream of the Rte 33 Bridge resulting from the removal of the Winnicut Dam would, however, provide enhanced conditions for the assessment and construction of remedial scour countermeasures and long-term monitoring of the countermeasures.

While the Rte 33 Bridge has been in place since 1959 and has experienced a number of flood events, including an event in October 1996 flood event which had an estimated return interval in excess of 100 years, no documentation of scour was located as part of this study. Nonetheless, the bridge scour methodologies in HEC-18 and applied in this study provide an envelope of potential scour conditions.

Table 8: Synopsis of Bridge Scour Calculations

	Hydrologic Event									
	10 year		***25 year***		***50 year***		***100 year***		***500 year***	
Dam In (Existing) Geometry										
General (Contraction) Scour (ft)	7.9		11.4		14.0		17.1		26.0	
Local (Abutment) Scour (ft)	9.0	10.1	11.2	11.4	12.1	12.3	13.6	13.8	19.1	16.9
Total Scour (ft)	17	18	23	23	26	26	31	31	45	43
Dam Out Geometry										
General (Contraction) Scour (ft)	8.2		11.4		13.9		17.1		26.0	
Local (Abutment) Scour (ft)	9.0	10.1	11.7	11.8	12.7	12.9	14.1	14.2	19.6	17.3
Total Scour (ft)	17	18	23	23	27	27	31	31	46	43
Difference in Calculated Scour (Dam In – Dam Out [ft])	0	0	0	0	-1	-1	0	0	0	0

Bridge Scour Countermeasures

While the existing bridge scour countermeasures under the Rte 33 Bridge appear to have been constructed in accordance with the original design, they are at the limit of the stability of the rock riprap used in their construction, and are currently failing. This has resulted in the exposure of the tops of the piles supporting the stub abutment and the sloughing of riprap into the channel of the Winnicut River under the Rte 33 Bridge. Observations of loose rock and overly steep slopes made in the course of the Feasibility Study indicate that much of the existing riprap under the bridge is in a state of incipient failure.

It is therefore likely that this material will continue to slough downward into the Winnicut River, leading to additional exposure and potential corrosion of the exposed piles and further constriction of the stream channel under the bridge. While the 1959 bridge plans suggest that the original bridge design would have provide for a channel approximately 7 feet deep and 10 feet wide at the bottom under the bridge at normal flow conditions, the existing channel is less than 3 feet deep with a bottom width of approximately 5 feet.

Based on these factors, it is recommended that a revised countermeasure plan be developed and implemented at the Rte 33 Bridge. Do the space limitations under the bridge and the ongoing failure of the existing riprap countermeasures, it is recommended that this plan incorporate fixed structures, such as retaining walls, to provide a long-term solution to bridge scour at the Rte 33 Bridge.

3.5.2 Municipal Uses - Fire Water

Municipal use of the impoundment created by the Winnicut Dam was evaluated as part of this study. The only identified municipal usage of the impoundment was by the Greenland Fire Department. It was determined based on a discussion with Greenland Fire Chief Ron Hussey that the Greenland Fire Department uses the impoundment as a source of water for fire suppression and for equipment maintenance. The fire department accesses the impoundment from the gravel parking area adjacent to the west abutment of the dam.

While there is currently no dry hydrant at the impoundment, the fire department is able to fill their tanker trucks at all times of the year due to the sufficient depth upstream of the dam. Water is drawn through 6-inch diameter suction lines with pumps rated at 20 feet of net-positive suction-head (NPSH). The Greenland Fire Department also uses water from the impoundment for routine equipment maintenance and annual pump certification as required by the National Fire

Protection Association. Chief Hussey explained that the Newington Fire Department also uses the pond for similar pump certification purposes.

3.5.3 Water Wells

While a public water distribution system serves most of the users on the east side of the Winnicut River in Greenland, residential and commercial water wells occur on both sides of the river along the impounded reach, including shallow (i.e., overburden) and deep wells. A qualitative evaluation of groundwater resources in the vicinity of the Winnicut Dam is presented in Section 3.4).

As part of the Feasibility Study, survey was performed to determine the number and types of wells adjacent to the Winnicut River upstream of the Winnicut Dam (Appendix 12). Questionnaires were mailed to abutters along the river upstream of the dam for this survey. A total of six questionnaires were returned, one of which indicated that the home was supplied by the municipal water distribution system that serves portions of Greenland east of the Winnicut River. One of the responses provided no information on the type or depth of the well. Two of the responses indicated drilled wells with depths of 50 and 600 feet, respectively. For the purpose of this study, the 50 feet depth well could be considered a shallow well. Two responses indicated shallow wells, one of which is clearly a dug well, based on the casing diameter of 30 inches, while the other suggested that the depth of the well 'might' be 50 to 90 feet

Overall, the responses to this survey indicate that there are three shallow wells in the adjacent to the impoundment on the Winnicut River upstream of the Rte 33 Bridge.

3.5.4 USGS Gage

The United States Geological Survey (USGS) currently maintains and operates a stream gaging station (No. 01073785) on the Winnicut River at the Winnicut Dam. The gage is configured to provide real-time stage and flow data for the Winnicut River at the dam. The gage location upstream of the Winnicut Dam is well suited for streamflow gaging on account of the hydraulic control imposed by the dam, The gage's pressure sensor unit is mounted

USGS streamgage telemetry equipment at Winnicut Dam – September 2003 below the water surface on the outside wall of the fish ladder adjacent to the west abutment of the Winnicut Dam, and is connected to a data transmission unit mounted inboard of the fish ladder above the left abutment of the dam.

Removal of the dam would likely eliminate the suitability of the current site for the gaging of streamflows, as the influence of tides propagating upstream from Great Bay would preclude the development of a monotonic stage-discharge relationship at the current location. Preliminary observations indicate that continued gaging of streamflows in the vicinity of the Winnicut Dam would require that the gage be situated upstream of the Rte 33 Bridge.

Observations made in the course of the Feasibility Study indicate that the strong hydraulic control imposed by the channel under the Rt. 33 Bridge would be suitable for gaging of flows through the installation of stage-measurement equipment at the upstream end of this channel.

3.6 SOCIO-ECONOMIC ISSUES

Three public meetings were held in Greenland to inform area residents of the purpose of the Feasibility Study and to solicit feedback regarding potential alternatives. In conjunction with the Greenland Conservation Commission, public information sessions were held during the evenings of August 11th, November 10th, and November 20th at the Greenland Town Hall. While there were generally no objections to dam modifications that would improve fish passage, some citizens expressed concern that the loss or lowering of the existing impoundment upstream of the Winnicut Dam and the Rte 33 Bridge could adversely affect recreational boating, fishing, and the value of properties with river frontage. During a meeting with representatives of the YMCA's Camp Gundalow in the course of this study, a representative of the YMCA stated the YMCA would not support alternatives that would substantially affect the YMCA's use of the impoundment for recreational boating.

In addition to the public meetings, a letter requesting feedback on potential adverse and beneficial impacts was sent to 35 riverfront property owners located upstream and downstream of the dam. The only response received was a note on the well water questionnaire that expressed opposition to eliminating the dam. A copy of the letter and the one response are included in Appendix 12.

Landscape companies currently fill water tanks at the impoundment adjacent to the west abutment of the Winnicut Dam. Discussions with one landscape contractor on site indicated the Winnicut impoundment is one of only three locations in the area that commercial tank trucks can easily access large volumes of suitable surface water.

In conclusion, public comments to dam modification suggest that there is more support for limited modifications impacting the existing impoundment, and increasing resistance to any changes that would lower upstream river levels. These comments suggest that area residents favor alternatives that would improve fish passage but only if water levels south of the Rte 33 Bridge are maintained at or close to current levels.

3.7 RECREATIONAL USE

3.7.1 Fishing

The Winnicut River currently provides limited cold water recreational fishing resources in the vicinity of the Winnicut Dam. This resource is comprised of a "put-and-take" fishery for stocked trout. In addition, a fishery for resident warmwater species occurs, though this is limited between the dam and Rte 33 because of the small size of that area. There is currently no recreational fishery associated with the anadromous rainbow smelt or river herring. Although references to a recreational fishery for rainbow smelt in Greenland Bay where the Winnicut River enters Great Bay were located in the course of the Feasibility Study, this fishery does not appear to have persisted.

The existing put-and-take fishery for stocked trout is popular, as it represents one of the few options for trout fishing in the Seacoast Region. Trout are stocked in the Winnicut River between the Winnicut Dam and the Rte 33 Bridge on a regular basis in the spring of each year. Residents of Greenland as well as residents of other, nearby towns, utilize this fishery. Although there is a limited trout fishery in upstream reaches of the Winnicut River, the lack of suitable access and the apparently limited dispersal of the stocked fish effectively confines this fishery to the impoundment between the dam and the bridge. In the course of the Feasibility Study, up to a half dozen anglers were observed fishing in the impoundment between the dam and the bridge at a given time. Inquiries suggest that this fishery represent the primary use of the Winnicut River for local anglers. Due to unsuitable water conditions associated with increased temperatures during the summer months, this fishery does not persist beyond June. There is no indication that any of the stocked trout survive through the summer and hold over within the Winnicut River system.

There is a limited fishery for resident warmwater fish in the Winnicut River in the vicinity of the Winnicut Dam. Species of primary interest for this fishery include bass, pickerel, and sunfish.

There is no indication that recreational fishing for saltwater fish (e.g., striped bass [*Morone* *saxatilis*]) occurs in the tidal reach of the Winnicut River immediately downstream of the Winnicut Dam.

3.7.2 Boating

Canoes at YMCA Camp Gundalow – April 2003

The impoundment created by the Winnicut Dam provides opportunities for recreational boating in the Winnicut River. Due to the limited size and depth of the impoundment and the volume of woody debris in the channel, this use is limited to a reach of river approximately one mile long, and canoes and kayaks appear to be the preferred type of vessel. Recreational boating is pursued primarily by abutters of the impoundment and by users of the Seacoast YMCA's Camp Gundalow. A limited number of recreational boaters launch boats between the Winnicut Dam and the Rte 33 Bridge and paddle into the impounded reach of river upstream of the Rte 33 Bridge. While additional access points to the river are available upstream of the Rte 33 Bridge, including the town park located on the east side of the river immediately upstream of the Rte 33 Bridge and various locations along Winnicut Road, these points do not appear to experience substantial use.

Upstream of the impoundment created by the Winnicut Dam, the Winnicut River is typically less than 15 feet wide and is not suitable for boating except by motivated boaters, as the river is shallow and choked with vegetation for most of the annual growing season.

3.7.3 Other Recreational Uses

Other recreational uses of the Winnicut River include swimming, cross-country skiing, snowshoeing, ice-skating, snowmobiling, and waterfowl hunting. Swimming occurs infrequently in association with activities at the YMCA's Camp Gundalow. When ice is sufficient, the impounded reach is used by abutters and local residents for cross-country skiing, snowshoeing, ice-skating and snowmobiling. While waterfowl hunting has historically occurred along portions of the impoundment reach, as evidenced by a duck blind situated on the west bank of the river approximately 1,500 feet upstream of the Rte 33 Bridge, ongoing development along the river likely precludes ongoing usage for this activity.

3.8 CULTURAL AND HISTORIC RESOURCES

An assessment of cultural and historic resources in the vicinity of the Winnicut Dam was performed as part of the Feasibility Study to evaluate potential impacts associated with the removal of the Winnicut Dam. This work included the development of a Project Area Form as part of a Phase I assessment of historic, architectural, and engineering resources and a Phase IA Archaeological Reconnaissance-level survey. In accordance with guidelines set forth by NHDES's *Dam Removal and River Restoration Program*, the evaluation of historic and cultural resources as part of the Feasibly Study falls under the purview of Section 106 of the National Historic Preservation Act of 1966.

3.8.1 Phase I Assessment of Historical, Architectural, and Engineering Resources

A Phase I assessment of historical, architectural, and engineering resources, including the development of a Project Area Form, was performed as part of the Feasibility Study (Appendix 1). As discussed in the Statement of Integrity in the Project Area Form, the Winnicut Dam project area has very little integrity with regard to historical, architectural, and engineering resources as none of the historic resources at the site, such as previous dams, mills, and houses remain at the site in their entirety.

3.8.2 Phase IA Archaeological Reconnaissance-level Survey

A Phase IA Archaeological Reconnaissance survey was performed as part of the Feasibility Study (Appendix 1). This survey was undertaken to determine the potential effects of the removal of the Winnicut Dam on cultural resources within the project area. The archaeological study evaluates two primary impacts zones: "near field effects" and "far-field effects." The near-filed effects portion encompasses the area 200 feet downstream and 375 feet upstream of the dam, as well as the surrounding embankments to a maximum distance of 66 feet. The far-field effects portion encompasses a backwater extent of 1.4 miles upstream of the dam, with a vertical impact area of 1 foot, as determined by the extent of the existing backwater and approximate drawdown of the impoundment upstream of the Rte 33 Bridge that would result form the removal of the Winnicut Dam.

Spit of land upstream of Rte 33 Bridge assigned moderate historic and prehistoric sensitivity (to right of channel) – August 2003

Three historic mill foundation/retaining wall elements and a set of granite bridge abutments were identified during the walkover survey of the Winnicut Dam project area. These cultural features are associated with the former Burleigh fulling mill/Union Mills complex, ca. 1821-1895, the Bracket/Holmes mill, ca. 1898-1942, and the historic road alignment of Rte 101/Portsmouth Avenue (now Rte 33).

Based on the prevailing environment conditions and documented historic resources and structures, the near-field portion of the project area was assigned moderate to high historic archaeological sensitivity and low prehistoric archaeological sensitivity. The majority of the far-field effects portion of the project area was assigned low archaeological sensitivity with the exception of a small spit of land immediately upstream of the Rte 33 Bridge that was assigned moderate historic and prehistoric sensitivity.

The sensitivity assessment and recommendation provided in the Phase IA report are based on preliminary construction plans and preliminary models concerning potential hydrologic effects associated with the removal of the Winnicut Dam. If plans for the removal of the Winnicut Dam are formalized, it is recommended that the project proponents consult with the New Hampshire Department of Historical Resources concerning potential construction impacts with area assigned moderate to high archaeological sensitivity. In the event that proposed impacts exceed the area of potential effects as defined in the Phase IA report, additional Phase IA survey will be required.

4.0 IMPACT ASSESSMENT

4.1 INTRODUCTION

Direct and indirect adverse and beneficial impacts to the affected environment were assessed for the three primary alternatives presented in this study. Additionally, impacts were evaluated with respect to existing conditions and the established goals of the project, namely the restoration of diadromous and resident fish populations in the Winnicut River and the enhancement of the overall ecological function of the Winnicut River. A qualitative rating system was used and was based on the assignment of varying levels of intensity of those impacts.

Levels of intensity refers to severity of the impact, whether it is negligible, minor, moderate, or major. The gradient of this system can be general or very detailed, but ultimately the assumptions and subjectivity of the system affect its sensitivity. A simple and subjective rating system was used, which included a rating scale of “no effect, negligible, minor, moderate, and major effects.” The authors of this study based the rating system score on professional opinion and took into account the context or setting of the action and its resulting impact.

The definition of no effect would be the same for each of the general impact topics. No effect would mean that no measurable effects could be recorded or surmised. Furthermore, the following definitions are used for the other, qualitative rating.

- *Negligible:* Impacts would not be detectable, measurable, or observable.
- *Minor:* Impacts would be detectable, but not expected to have an overall effect on the resource.
- *Moderate:* Impacts would be clearly detectable and could have short-term, appreciable effects on the resource.
- *Major:* Long-term or permanent, highly noticeable effects on the resource.

4.2 ALTERNATIVE A – NO ACTION ALTERNATIVE

4.2.1 Ecological Resources

Fisheries

Implementation of Alternative A would result in major adverse impacts and negligible beneficial impacts to the target fish in the Winnicut River. Adverse impacts associated with this alternative result from that lack of increased access to spawning habitat for smelt and river herring. The lack of readily available spawning habitat for the target species could have broad implications for the long-term viability of the target fish species in the Winnicut River. Specific factors that create vulnerability of these fish include that the lack of meta-populations that can result from spawning over a greater extent of river and the potential loss of year classes due to catastrophic events covering the existing, limited spawning areas.

Wetlands

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to wetlands in the vicinity of the Winnicut Dam.

Wildlife

Implementation of Alternative A would result in minor adverse impacts and no beneficial impacts to wildlife in the vicinity of the Winnicut Dam. Adverse impacts associated with this resource would result from the loss of additional forage, as represented by adult and juvenile river herring, in the Winnicut River upstream of the Winnicut Dam relative to benefits provided by the other alternatives.

4.2.2 Hydrology, Hydraulics, and Fluvial Processes

Hydrology and Hydraulics

Implementation of Alternative A would result in minor adverse impacts and negligible beneficial impacts to the hydrology and hydraulics of the Winnicut River in the vicinity of the Winnicut Dam. The adverse impacts are associated with lack of flushing and the ongoing eutrophication of the impoundment upstream of the Winnicut Dam.

Flooding

Implementation of Alternative A would result in negligible adverse impacts and no beneficial impacts to the existing flood regime on the Winnicut River in the vicinity of the Winnicut Dam.

Sediment Transport

Implementation of Alternative A would result in minor adverse impacts and no beneficial impacts to sediment transport in the Winnicut River in the vicinity of the Winnicut Dam. The adverse impacts would be associated with the continued deposition of sediments in the Winnicut River, particularly in the reach immediately upstream of the Rte 33 Bridge. The continued trapping of sediments and nutrients in the existing impoundment would likely result in the long-term deterioration of water quality in the impounded reach of the Winnicut River.

Transitional wetland in impoundment above old dam and road crossing – April 2003

The photo to the right shows a reach of the Winnicut River approximately one mile upstream of the Rte 33 Bridge that was previously impounded by an old dam and road crossing. Over time, sedimentation in this area has resulted in the transition of what was likely an impoundment into a marsh with a well-defined channel. Over time, similar morphological and ecological conditions are likely to develop in the impoundment upstream of the Rte 33 Bridge due to the continued trapping of sediments in the impoundment.

4.2.3 Groundwater

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to the groundwater resources adjacent to the Winnicut River in the vicinity of the Winnicut Dam.

4.2.4 Infrastructure

Rte 33 Bridge

Implementation of Alternative A would result in negligible adverse impacts and negligible beneficial impacts associated with scour in the vicinity of the Rte 33 Bridge. While the backwater created by the Winnicut Dam likely mitigates scour in the vicinity of the Rte 33 Bridge, the continued presence of the dam does not eliminate the need for the reconstruction of the existing scour countermeasures, which are currently failing.

Municipal Usage of Impoundment

Implementation of Alternative A would result in no adverse impacts and moderate beneficial impacts to municipal usage of the impoundment immediately upstream of the Winnicut Dam. The beneficial impact was assigned based on the prevailing use of the impoundment for fire prevention relative to adverse impacts associated with Alternative C.

Water Wells

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to water wells in the vicinity of the Winnicut Dam.

USGS Streamflow Gage

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to the USGS streamflow gage at the Winnicut Dam.

4.2.5 Socio-Economic Issues

Implementation of Alternative A would result in negligible adverse impacts and negligible beneficial impacts with regard to socio-economic issues associated with this study.

4.2.6 Recreational Use

Fishing

Implementation of Alternative A would result in negligible adverse impacts and negligible beneficial impacts to the existing recreational fishery in the impoundment immediately upstream of the Winnicut Dam.

Boating

Implementation of Alternative A would result in negligible adverse impacts and negligible beneficial impacts to recreational boating in the impoundment created by the Winnicut Dam.

Other Recreational Uses

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to other recreational uses of the impoundment created by the Winnicut Dam, such as cross-country skiing, snowshoeing, ice-skating and snowmobiling.

4.2.7 Cultural and Historic Resources

Implementation of Alternative A would result in no adverse impacts and no beneficial impacts to cultural and historic resources in the vicinity of the Winnicut Dam.

4.3 ALTERNATIVE B – IMPROVED UPSTREAM FISH PASSAGE AT THE WINNICUT DAM

4.3.1 Ecosystem

Fisheries

Implementation of Alternative B would result in major adverse impacts and major beneficial impacts to the target fish in the Winnicut River. Adverse impacts associated with this alternative relative to rainbow smelt. This alternative would result in no additional spawning habitat for smelt (i.e., that area between the dam and Rte 33 that could become spawning habitat if the dam were removed). In addition, any type of fish passage at the dam, even the most technologically advanced, would not pass rainbow smelt above the dam as this species does not use fish passage structures. The lack of readily available spawning habitat for smelt has broad implications for the long-term viability of this fish species in the Winnicut River. Specific factors that create vulnerability of these fish include that the lack of meta-populations that can result from spawning over a greater extent of river and the potential loss of year classes due to catastrophic events covering the existing, limited spawning areas.

Beneficial impacts associated with this alternative result from enhanced access to suitable spawning habitat for river herring.

Wetlands

Implementation of Alternative B would result in no adverse impacts and no beneficial impacts to wetlands upstream of the Winnicut Dam. The implementation of Alternative B would result in no change to the existing water levels or flow regimes upstream or downstream of the Winnicut Dam. This determination is based on the assumption that the installation and operation of a more effective type of fishpass at the Winnicut Dam would not result in any changes to the existing water levels in the upstream impoundment. .

Depending on the design and construction needs for the technical fishpass, it is possible that there could be direct impacts to an area of existing tidal wetland at the base of the dam.

Wildlife

Implementation of Alternative B would result in negligible adverse impacts and major beneficial impacts to wildlife in the vicinity of the Winnicut Dam. Beneficial impacts associated with this resource result from the presence of increased numbers of forage fish, as represented by adult and juvenile river herring, in the Winnicut River upstream of the Winnicut Dam.

4.3.2 Hydrology, Hydraulics, and Fluvial Processes

Hydrology and Hydraulics

Implementation of Alternative B would result in minor adverse impacts and no beneficial impacts to the hydrology and hydraulics of the Winnicut River in the vicinity of the Winnicut Dam. The adverse impacts are associated with lack of flushing and the ongoing eutrophication of the impoundment upstream of the Winnicut Dam.

Flooding

Implementation of Alternative B would result in negligible adverse impacts and no beneficial impacts to the existing flood regime on the Winnicut River in the vicinity of the Winnicut Dam.

Sediment Transport

Implementation of Alternative B would result in minor adverse impacts and no beneficial impacts to sediment transport in the Winnicut River in the vicinity of the Winnicut Dam. The adverse impacts would be associated with the continued deposition of sediments in the Winnicut River, particularly in the reach immediately upstream of the Rte 33 Bridge.

4.3.3 Groundwater

Implementation of Alternative B would result in no adverse impacts and no beneficial impacts to the groundwater resources adjacent to the Winnicut River in the vicinity of the Winnicut Dam.

4.3.4 Infrastructure

Rte 33 Bridge

Implementation of Alternative B would result in negligible adverse impacts and negligible beneficial impacts associated with scour in the vicinity of the Rte 33 Bridge. While the backwater created by the Winnicut Dam likely mitigates scour in the vicinity of the Rte 33

Bridge, the continued presence of the dam does not mitigate the need for the reconstruction of the existing scour countermeasures, which are currently failing.

Municipal Usage

Implementation of Alternative B would result in no adverse impacts and moderate beneficial impacts to municipal usage of the impoundment immediately upstream of the Winnicut Dam. The beneficial impact was assigned based on the prevailing use of the impoundment relative to adverse impacts associated with Alternative C.

Water Wells

Implementation of Alternative B would result in no adverse impacts and no beneficial impacts to water wells in the vicinity of the Winnicut Dam.

USGS Streamflow Gage

Implementation of Alternative B would result in minor adverse impacts and no beneficial impacts to the USGS streamflow gage at the Winnicut Dam. The adverse impacts result from the likely need to recalibrate the stage discharge curve used to determine flows at the gaging station.

4.3.5 Socio-Economic Issues

Implementation of Alternative B would result in negligible adverse impacts and moderate beneficial impacts with regard to socio-economic issues associated with this study. The beneficial impacts result from the increased number of river herring in the Winnicut River upstream of the Winnicut Dam and the commensurate increased awareness of natural resources and their dependence on the human stewardship.

4.3.6 Recreational Use

Fishing

Implementation of Alternative B would result in negligible adverse impacts and moderate beneficial impacts to the existing recreational fishery in the impoundment immediately upstream of the Winnicut Dam. Beneficial impacts would result from improvements to the fishery for resident fish in the Winnicut River, such as bass, pickerel, and sunfish due to increased forage in the form of young-of-year river herring, and the potential creation of a recreational fishery for river herring.

Boating

Implementation of Alternative B would result in negligible adverse impacts and negligible beneficial impacts to recreational boating in the impoundment created by the Winnicut Dam.

Other Recreational Uses

Implementation of Alternative B would result in negligible adverse impacts and negligible beneficial impacts to other recreational uses of the impoundment created by the Winnicut Dam, such as cross-country skiing, snowshoeing, ice-skating and snowmobiling.

4.3.7 Cultural and Historic Resources

Implementation of Alternative B would result in negligible adverse impacts and no beneficial impacts to cultural and historic resources in the vicinity of the Winnicut Dam. Adverse impacts would result from the potential soil disturbance associated with the construction of a technical fishpass within the concrete walls of the existing fish ladder.

4.4 ALTERNATIVE C – REMOVAL OF THE WINNICUT DAM AND CONSTRUCTION OF A TECHNICAL FISHPASS UNDER THE RTE 33 BRIDGE

4.4.1 Ecosystem

Fisheries

Implementation of Alternative C would result in negligible adverse impacts and major beneficial impacts to the target fish in the Winnicut River. Beneficial impacts associated with this alternative include additional spawning habitat for smelt, enhanced access to suitable spawning habitat for river herring, safe downstream passage for juvenile river herring, and rearing and foraging habitat for American eels.

Wetlands

Alternative C would result in some adverse impacts to wetlands abutting the impoundment upstream of the Winnicut Dam. In general, these impacts would be temporal, however, as a new wetland fringe would develop downslope from the existing wetlands. Between the Winnicut Dam and the Rte 33 Bridge, the steep banks limit the development of wetlands to a narrow fringe. However, wetlands would likely develop in the relatively flat area along at the bottom of the existing impoundment, and could result in an increase in the areal extent of wetlands.

Photo-simulation of Winnicut River at Winnicut Dam with dam removed. View is looking downstream from the abandoned bridge abutments. Note that view includes area that could become suitable smelt spawning habitat.

Upstream of the Rte 33 Bridge, the implementation of this alternative would likely result in no substantial loss of wetlands. New wetlands would likely develop along the new impoundment boundaries, as the lower water levels would result in a commensurate change in the hydrology of the abutting wetlands. On a seasonal basis, the hydrology of this new fringe wetland would be similar to that of the existing fringe wetland. Depending upon the morphology of the existing impoundment, implementation could result in an increase in the areal extent of wetlands in the impoundment, particularly if the proposed drawdown results in the creation of shallow areas suitable for colonization by wetland plants. Figure 14 illustrates approximately where these wetland impacts would be expected to occur within the impoundment, based on the best available information.

Extent of Wetland Impacts Expected

No direct effects to wetlands would be expected in survey Reaches 1 and 2 (refer to Figure 6), which are entirely upstream of the limit of backwater influence. Indirect effects to wetlands in Reaches 1 and 2 could be realized by the re-introduction of diadromous fisheries into these areas, including changes to aquatic floral and faunal community structure and function. These effects are difficult to predict, but can be considered mostly beneficial if the overall goal is to restore aquatic natural communities that were present about 350 years ago before any dams were placed on this river.

Though it is clear that changes to wetland hydrology within palustrine and riverine wetlands will occur as a result of the one to two foot drawdown upstream of the Rte 33 Bridge, the best available information does not allow an accurate prediction of changes in the net area of wetland habitat or the relative proportions of the various wetland community types. The preliminary predictions outlined below are based on observations of the impoundment by Woodlot field biologists during the maintenance of the Winnicut Dam in 2003. The portions of the impoundment that would likely experience some type of wetland change are shown on Figure 14. Table 9 provides a summary of the areal extent of expected changes.

Table 9: Summary of Expected Changes to Wetland From Implementation of Alternative C.

Location of Specific Reach (Refer to Figure 14)	Estimated area of Wetland Change (Sq. Feet.)	Comments
Between Winnicut Dam and Rte 33 Bridge	21,000	Estimated area includes an existing pool that would be permanently dewatered except for +/- 25’ wide river channel. Impacts would include creation of uplands and palustrine wetlands.
From Rte 33 Bridge to Point 1,600 Feet Upstream	16,000	Estimated area includes a 5’ wide (ave.) fringe that would be dewatered. Impacts would mostly include changes in wetland types.
Near YMCA Camp Gundalow	14,000	Estimated area includes riverside fringe and floodplain wetlands that would be dewatered in summer. Impacts would mostly include changes in wetland types.
Total Estimated Area	51,000 Sq. Feet. = 1.2 Acres	

It is expected that removing the dam would reduce the width and depth of the open water within the river in some, but not all, areas of the impoundment. For example, the reach between the

Winnicut Dam and the Rte 33 Bridge will experience a drawdown of approximately 10 feet, leaving only the remnant channel watered, and resulting in the dewatering of approximately 21,000 square feet of former pool habitat. It is expected that this dewatered area would be converted into a mixture of wetland and upland habitats.

In contrast, the water levels in the reach extending 1,600 feet or so upstream of the Rte 33 Bridge would only be expected to drop 1.0 to 1.5 feet, with progressively less change expected from downstream to upstream locations. Based on observations made during the maintenance drawdown, it is expected that the locations and extent of dewatered area in this reach would vary, depending on the bathymetric characteristics of the channel, with some shoreline sections experiencing essentially no change due to the presence of steep-sided banks. Overall, it is estimated that the area affected by the drawdown here would be limited to an average of approximately 5 horizontal feet of shoreline on either side of the river, or approximately 16,000 square feet in area. Because these dewatered shoreline areas would still be flooded during spring and fall high water periods and seasonal wetland hydrology would likely persist, they would be expected to remain as wetland habitats, becoming a fringe of shallow aquatic, emergent, shrub communities.

The only other wetland areas expected to experience possible changes as a result of permanent drawdown are located near the YMCA's Camp Gundalow, in an stretch of river extending from approximately 2,800 to 3,300 feet upstream of the Rte 33 Bridge (Figure 14). It is predicted that this reach would experience a maximum summer drawdown of about 1 foot if the dam were to be removed. This magnitude of drawdown would not be expected to result in large impacts to wetlands in this area. There may be slight shoreward migration of palustrine emergent and shrub wetland habitats that would simply replace portions of the permanently inundated riverine habitat that become exposed during summer low flow periods. While it is estimated that the area affected by this change would affect approximately 13,000 to 15,000 square feet of existing wetlands, implementation of this alternative could result in a net increase in wetland habitat along the Winnicut River.

<u>Types of Wetland Impacts or Changes Expected</u>

It is expected that wetland impacts resulting from Alternative C would be limited to the portions of the impoundment currently influenced by pronounced backwater effects during periods of low-flow. Lowering the summer water levels would affect the existing wetlands within and adjacent to in the impoundment in one of two ways: (1) draining the wetland and removing the source of hydrology (e.g., soil saturation or inundation); or (2) changing the hydrologic regime such that the level or duration of saturation or inundation is reduced. Depending on the vertical extent of permanent drawdown, draining may result in the conversion of wetland habitat into upland habitat. In the same way, lesser changes to the hydrologic regime may result in the conversion of one wetland type into another, or in the migration of a particular wetland type downslope towards the new, lowered water surface. For example, fringes of shrub wetland may be converted into forested wetland, emergent wetlands may be converted to shrub wetland, shallow aquatic may be converted to emergent, and shallow aquatic wetland habitat may shift toward the channel and replace deep aquatic habitat or unvegetated aquatic areas.

Potential Impacts to Wetland During Construction

Potential impacts to wetlands adjacent to the Winnicut Dam were evaluated. This evaluation was performed by determining likely routes of access to the dam as part of a removal action and then delineating wetlands along the route. It was determined that the most likely route of access for removal of the dam would be immediately downstream (north) of the left (west) dam abutment. Wetlands were delineated in this area, as shown in Figure 15. Actual extents and types of impacts to these wetlands would be dependent on the type and size of equipment required for removal of the dam.

Invasive Plants

Another potential change resulting from Alternative C would the increased opportunity for colonization of exposed sediments by invasive plant species. To a great extent the likelihood of this impact is dependent on the underlying soils and characteristics of the seed bank. If the underlying soils in these fringe areas have high percentage of fines, and particularly organic materials, then the capillary rise of water could result in the persistence of the existing wetland vegetation.

Exposing previously inundated or vegetated soils can result in quick colonization of these areas by volunteer weedy plants. Two highly invasive wetland plant species, purple loosestrife and reed canary grass, are found in relatively high concentrations along portions of the river just upstream of the Winnicut Dam impoundment. Purple loosestrife is a non-native and particularly aggressive plant that is becoming a large problem in the region because it forms dense stands that can crow out native plants. Reed canary grass is actually a native plant, and though it aggressively colonizes disturbed wetland areas, it would be much preferable to loosestrife because it is native. Japanese knotweed (*Fallopia japonica*), an aggressive invasive that prefers sunny upland areas, is also found along the banks of the impoundment near the dam. It is possible that these invasive plant species, and possibly others as well, could colonize any areas of newly exposed soil.

While the management of invasive plant species should be addressed in any further development of this alternative, it is important to realize that it is not reasonable to expect the complete control or eradication of species. This is because some species, such as purple loosestrife, are already well established in the Winnicut River system. Rather, the goal should be limiting the spread of these plants to allow a diversity of native plant species to become well established and perpetuating.

There are two primary management methods that can be used to reduce the threat of colonization by plants of this type: 1) prompt seeding and planting of newly-exposed soils to establish dense, non-invasive native vegetation; and 2) removing any invasive plants that do seed in before they have a chance to become well established and plentiful. These options should be evaluated more fully once a decision of recommended actions at the site is made.

Establishing dense native vegetation will greatly reduce the amount of disturbed soil that leads to the colonization and spread of invasive plants, particularly for purple loosestrife and Japanese knotweed. The drawdown should be timed for early in the growing season (i.e., May or June).

The exposed soil should immediately be seeded with a mix of native herbaceous and shrub species specifically designed to provide a quick cover. Some type of biodegradable temporary erosion control blanket may be needed in some areas to further protect the exposed soils from unwanted colonization by invasive plants. In addition, containerized shrubs and trees should be planted to "jump start" the establishment of shade, which tends to prohibit or limit the growth of plants like reed canary grass and Japanese knotweed.

During the initial revegetation period, the areas at risk of colonization by invasive plants would have to be surveyed often in an effort to locate and remove any such plants that do become established. This can be labor-intensive and should be overseen by trained personnel, but is necessary if effective control is desired. Proven control methods include both mechanical and chemical treatments. Mechanical methods involve cutting and pulling plants by hand when they are just starting to come up, with care taken to minimize additional soil disturbance. Herbicides such as glyphosate can be effective in controlling the spread of invasive plants, but this chemical is non-selective and must be applied carefully to avoid damage to desirable plants. A licensed applicator is usually required when using herbicide in this type of situation.

Appendix 13 contains more detailed sample plans for controlling purple loosestrife and Japanese knotweed and a conceptual streambank stabilization detail incorporating native plantings.

<u>Effects on Wetland Functions and Values</u>

It is expected Alternative C would have various effects on the existing wetland functions and values associated with the impoundment (i.e., Reach 1), ranging from slight to moderate in magnitude. Fish and shellfish habitat would probably be most affected, primarily from the introduction of diadromous fish species and changes in flow regimes in some locations. This is closely tied to the project goals, and could be judged to be a moderate, albeit positive and desirable, change associated with the riverine wetland habitats (refer to Sections 1.1 and 4.1.1).

Recreation, namely fishing opportunities, would also be moderately affected. This change could be judged as both negative and positive, as some existing fishing opportunities would be eliminated (i.e., the put-and-take brook trout fishing between the dam and Rte 33 Bridge), while others will be potentially enhanced (e.g., fishing for alewife and resident warmwater species upstream of Rte 33 Bridge and rainbow smelt downstream of the dam).

Biomass export may be enhanced to varying degrees by removal of the dam. Increased access to spawning habitat should result in an overall increase in the river herring and rainbow smelt spawning population and subsequent juvenile population leaving the river, which provide forage for important commercial marine fish species in Great Bay and beyond. Removal of the dam could also enhance to a limited extent the flushing and export of nutrients from this wetland system into the tidal marshes and near-shore marine habitats of Great Bay. This increased export could benefit the overall level of productivity of plant and animal life inhabiting the bay, but that increase would likely be relatively small and difficult to quantify.

It is expected that wetland functions related to water quality, namely sediment, nutrient, and toxicant retention, would be affected very little by the implementation of Alternative C. With the dam removed, there may be slightly less capacity for sediment trapping within the impoundment area, which would theoretically put more of the burden on the adjacent wetlands to filter out some of this material during higher flows.

Flood control functioning will be similarly affected by the dam's removal. The Rte 33 Bridge is expected to impound waters to levels similar to the existing dam, which will continue to cause upstream forested and shrub wetlands to be flooded and allow them the opportunity to store and desynchronize flood flows. Flood control is, however, relatively unimportant in this portion of the watershed because of the proximity to Great Bay and the low potential for downstream flood damage.

The opportunity for the project area wetlands to provide educational/scientific value would be enhanced through the implementation of Alternative C. The efforts to restore diadromous fisheries and riverine ecosystems could include concurrent scientific studies to look at the short- and long-term effects of dam removal and fisheries re-introduction within the wetland systems upstream and downstream of the Winnicut Dam. Though these wetland types are relatively common and not particularly unique in this region, the opportunity for conducting studies greatly enhances the value of the wetlands from the standpoint of scientific value relative to other similar wetlands in the area.

Other wetland functions and values associated with the project wetlands, including shoreline stabilization, uniqueness/heritage/aesthetics, and endangered species habitat would not be expected to experience measurable changes if Alternative C were implemented.

Wildlife

Implementation of Alternative C would result in negligible adverse impacts and major beneficial impacts to wildlife in the vicinity of the Winnicut Dam. Beneficial impacts associated with this resource result from the presence of increased numbers of forage fish, as represented by adult and juvenile river herring, in the Winnicut River upstream of the Winnicut Dam. In addition, shorebird species would benefit slightly from the increased area of intertidal habitat for feeding.

Changes to the fish populations and species assemblages within the river would likely benefit wetland-dependent species such as river otter, osprey, and kingfisher by providing a larger and more diverse forage base. Open water habitat for waterfowl could decrease slightly, but not enough to affect use of the river by this group of wildlife species. Use of the river by opportunistic animals such as deer and raccoon is not expected to change. Upstream of the Rte 33 Bridge, the drawdown resulting from the dam removal could have short-term benefits to shorebird species by providing larger areas of exposed sediments for feeding. These benefits would not be expected to persist upstream of the dam because the exposed shoreline areas would become densely vegetated. In summary, it is expected that the overall effects of this alternative on wildlife would be small.

4.4.2 Hydrology, Hydraulics, and Fluvial Processes

Hydrology and Hydraulics

Implementation of Alternative C would result in minor adverse impacts and minor beneficial impacts to the hydrology and hydraulics of the Winnicut River in the vicinity of the Winnicut Dam. The beneficial impacts are associated with current lack of flushing and the ongoing eutrophication of the impoundment upstream of the Winnicut Dam.

Flooding

Implementation of Alternative C would result in no adverse impacts and minor beneficial impacts to the existing flood regime on the Winnicut River in the vicinity of the Winnicut Dam. While this alternative would allow tidal effects to propagate upstream of the current dam location to the downstream face of the Rte 33 Bridge, the selected level of adverse impacts was negligible, the calculated peak flood elevation for the 100-year tidal surge event as shown on the FIRM is lower than the invert of the proposed technical fishpass at its upstream end. Therefore, the tidal surge would not propagate upstream of the Rte 33 Bridge.

Beneficial impacts would result from the increased hydraulic conveyance under the Rte 33 Bridge and resulting reduction in upstream flood levels.

Sediment Transport

Implementation of Alternative C would result in negligible adverse impacts and minor beneficial impacts to sediment transport in the Winnicut River in the vicinity of the Winnicut Dam. The beneficial impacts would be associated with a minor increase in sediment transport through the impounded reach of the Winnicut River upstream of the Rte 33 Bridge and no trapping of sediments in the reach of river between the Winnicut Dam and the bridge.

4.4.3 Groundwater

Implementation of Alternative C would result in minor adverse impacts and negligible beneficial impacts to the groundwater resources adjacent to the Winnicut River in the vicinity of the Winnicut Dam. The adverse impacts would be associated with a minor drawdown of the groundwater table in the vicinity of the Winnicut Dam.

4.4.4 Infrastructure

Rte 33 Bridge

Implementation of Alternative C would result in minor adverse impacts and minor beneficial impacts associated with scour in the vicinity of the Rte 33 Bridge. While engineering judgment suggests that the implementation of this alternative would result in increased scour under the bridge, the level of intensity for adverse impacts was selected based on the apparent need for the reconstruction of the existing scour countermeasures, which are currently failing.

The level of beneficial impacts was selected because the implementation of this alternative would provide an opportunity for the development and implementation of revised scour countermeasures at the Rte 33 Bridge. Note that while the backwater created by the Winnicut Dam likely mitigates scour in the vicinity of the Rte 33 Bridge, the continued presence of the dam does not mitigate the need for the development and implementation of revised scour countermeasure under the Rte 33 Bridge.

If Alternative C did not incorporate the construction of a technical fishpass under the Rte 33 Bridge, the selected level of adverse impacts associated with scour at the Rte 33 Bridge would have been major due to the likely increased rate of failure of the existing scour countermeasures. While the bridge scour analysis presented in Section 3.5.1 concludes that increased scour would not result from the implementation of this alternative, the applied method of analysis does not account for all of the factors pertinent to realized scour. Engineering judgment suggests that this alternative would result in increased scour under the bridge with the existing scour countermeasures. As previously noted, however, the construction of the technical fishpass under the bridge, as incorporated in this alternative, affords the opportunity to develop and implement a revised scour countermeasure scenario under the Rte 33 Bridge.

A parameter associated with the stability of the Rte 33 Bridge and the adjacent approach embankments that was not evaluated as part of the Feasibility Study is the stability of the embankments with the increased hydraulic gradient that would result from the implementation of Alternative C. This alternative would result in a persistent hydraulic gradient (difference in water surface elevations between the upstream and downstream impoundments) of approximately 10 feet between the upstream and downstream faces of the embankment.

Municipal Usage

Alternative C would result in major adverse impacts and negligible beneficial impacts to municipal usage of the impoundment immediately upstream of the Winnicut Dam. Adverse impacts would result from the diminished feasibility of withdrawing water from the Winnicut River downstream of the Rte 33 Bridge due to a number of factors, such as a smaller volume of available impounded water, an increased elevation through which water would have to be pumped, and the potential for increased salinity of the withdrawn water.

The smaller volume of impounded water available for withdrawal would result from the lack of a large pool in the river in the vicinity of the existing dam where water is currently withdrawn. While a shallow pool was observed immediately downstream of the Rte 33 Bridge during the drawdown for dam maintenance in October 2003, this pool might not persist following the removal of the dam, and it might not impound a sufficient volume of water for fire suppression needs. Furthermore, the withdrawal of water from a pool downstream of the Rte 33 Bridge would require raising it over an elevation of approximately 16 feet. While the Greenland Fire Department currently uses a pump rated at 20 feet net-positive suction-head, the increased elevation combined with hydraulic head losses through the withdrawal hose could exceed pumps capabilities.

Tidal stage data measured at the base of the Winnicut Dam and bathymetric data obtained in the course of the Feasibility Study indicates that spring tides will inundate the Winnicut River to the downstream limit of the Rte 33 Bridge. This would result in high salinities in the water immediately downstream of the bridge during periods of low riverine flow (i.e., summer low flow conditions).

Potential means for mitigating impacts to municipal usage of the existing impoundment include development of water delivery systems in the immediate vicinity of the existing dam and the development of off-site water supplies.

Were the impoundment not to exist, Greenland Fire Chief Ron Hussey would request that a 30,000-gallon (4,000 cubic feet) concrete cistern be constructed in the vicinity to replace this water source. This cistern would be similar to those required in new developments that are not supplied with municipal water.

Water Wells

Alternative C would result in minor negligible impacts and negligible beneficial impacts to water wells in the vicinity of the Winnicut Dam.

USGS Streamflow Gage

Alternative C would result in minor adverse impacts and moderate beneficial impacts to the USGS streamflow gage at the Winnicut Dam. The adverse impacts result from the likely need to recalibrate the stage discharge curve used to determine flows at the gaging station.

Adverse impacts would result because tidal effects would preclude the ability to determine flow using a monotonic, stage discharge relation and therefore preclude the accurate gaging of stream flows at the existing gage location.

Because typical tides at in the vicinity of the project site would propagate upstream to the downstream embankment of the Rte 33 Bridge, reestablishment of a gage in the general vicinity of the existing gage would require its placement upstream of the limit of tidal influence. Preliminary evaluations suggest that the most suitable location would be at the upstream limit of the technical fishpass, as this area should provide hydraulic control and a stable cross-section geometry.

Beneficial impacts are associated with the potential to site the gage at the upstream end of the technical fishpass under the Rte 33 Bridge. Installation of the gage at this location would preclude the current need to recalibrate the gage rating-curve due to temporal variations associated with the seasonal operation of the existing fish ladder. In addition, the slightly smaller volume of the upstream impoundment coupled with the increased hydraulic conveyance of the channel (fishpass) under the Rte 33 Bridge would reduce some of the damping of hydrographs experienced at the existing gage location.

4.4.5 Socio-Economic Issues

Alternative C would result in moderate adverse impacts and major beneficial impacts with regard to socio-economic issues associated with this study. The moderate adverse impacts result from the fundamental changes to the landscape in the vicinity of the Winnicut Dam and the commensurate loss of the prevailing sense of place associated with this landscape.

The beneficial impacts result from the increased numbers smelt in the Winnicut River, the increased number of river herring in the Winnicut River upstream of the Rte 33 Bridge, and the commensurate, increased awareness of natural resources and their dependence on the human stewardship.

4.4.6 Recreational Use

Fishing

Alternative C would result in moderate adverse impacts and major beneficial impacts to the existing recreational fishery in the impoundment immediately upstream of the Winnicut Dam. Adverse impacts would result from the loss of the seasonal, put-and-take trout fishery in the impoundment immediately upstream of the Winnicut Dam. Beneficial impacts would also result from improvements to the fishery for resident fish in the Winnicut River, such as bass, pickerel, and sunfish due to increased forage in the form of young-of-year river herring, and the potential creation of a recreational fishery for river herring.

The NHFGD is currently exploring opportunities intended to mitigate the loss of the seasonal put-and-take fishery by providing a similar fishery at alternative locations in the vicinity of Greenland.

Boating

Alternative C would result in moderate adverse impacts and moderate beneficial impacts to the existing recreational fishery in the impoundment immediately upstream of the Winnicut Dam. Adverse impacts would be associated with the loss of a persistent impoundment suitable for recreational boating downstream of the Rte 33 Bridge and the inability to launch a boat downstream of the Rte 33 Bridge and access the river upstream of the bridge. Beneficial impacts would include improved access for recreational boating in the tidal reach of the Winnicut River downstream from the dam.

The level of intensity selected for the adverse impacts was based on the limited drawdown of the impoundment upstream of the Rte 33 Bridge required for the implementation of this alternative and the presence of other potential sites for launching small boats into the impounded reach. In essence, any recreational boating currently occurring upstream of Rte 33 could continue to exist under the conditions of this alternative. Potential alternative launching sites include the public park abutting Rte 33 and the river east of the bridge or other sites along Winnicut Road in Greenland.

The selected level of intensity of the beneficial impacts reflects the enhanced opportunity for launching small boats into the tidal portion of the Winnicut River immediately downstream of the Rte 33 Bridge. Currently, the lack of developed access points downstream of the Winnicut Dam all but precludes access to the tidal reach of the Winnicut River within Greenland.

If the selected level of intensity for adverse impacts to recreational boating was selected based only on impacts to the water levels in the Winnicut River upstream of the Rte 33 Bridge, the level of intensity of adverse impacts would have been selected as minor, as the drawdown of the impoundment resulting from the implementation of this alternative would be minimal (1 to 2 feet).

Other Recreational Uses

Alternative C would result in negligible adverse impacts and negligible beneficial impacts to other recreational uses of the impoundment created by the Winnicut Dam, such as cross-country skiing, snowshoeing, ice-skating and snowmobiling.

4.4.7 Cultural and Historic Resources

Alternative C would result in minor to moderate adverse impacts and no beneficial impacts to cultural and historic resources in the vicinity of the Winnicut Dam. Adverse impacts would result from the potential soil disturbance associated with the removal of the Winnicut Dam, the construction of a technical fishpass under the Rte 33 Bridge, and the full and partial dewatering of the impoundments between the dam and the Rte 33 Bridge and upstream of the bridge, respectively.

The varying levels of adverse impacts were assigned because it cannot be determined in advance whether actual resources would be exposed as a result of construction activities, erosion, or vandalism as a result of the removal of the Winnicut Dam. A major level of adverse impacts was not assigned because of the following factors:

a) The construction of the Winnicut Dam in 1957 likely resulted in the disturbance of adjacent resources during its construction;

b) The construction of the Rte 33 Bridge in 1959 likely resulted in the disturbance of adjacent resources during its construction; and

c) The area upstream of the Winnicut Dam was dewatered between 1941 when the previous dam washed-out and 1957 when the current dam was built. Note that during this time there was no impoundment upstream of the abandoned Route 101 bridge located immediately downstream of the Rte 33 Bridge.

d)

5.0 SUMMARY OF FEASIBILITY ASSESSMENT

5.1 INTRODUCTION

The purpose of this Feasibility Study was to evaluate alternatives for achieving project goals for the restoration of diadromous and resident fish populations in the Winnicut River and the enhancement of overall ecological function in the river. Eight conceptual alternatives were initially developed as part of this study, with three of these alternatives, including a No Action alternative, being advanced to the status of "primary alternative." These primary alternatives were subsequently evaluated for their ability to achieve the project goals and on potential impacts to resources, or "constraints," in the vicinity of the Winnicut Dam. The evaluation of adverse and beneficial impacts to resources assessed ecological, hydrology, hydraulic and fluvial processes, groundwater, infrastructure, socio-economic, recreational, and cultural and historic factors.

5.2 SYNOPSIS OF ALTERNATIVES

A brief description of the three primary alternatives developed and evaluated as part of this study is presented below. A full description of these alternatives is presented in Section 2.0. A summary of the respective strengths of the primary alternative associated with their ability to achieve the project goals is presented in Table 10.

5.2.1 Alternative A – No Action

Alternative A, a No Action alternative, would provide for no changes to the existing condition or operation of the Winnicut Dam. This alternative was evaluated as a baseline for the comparison of the other primary alternatives. While implementation of Alternative A is easily feasible, it would not achieve the project goals and would result in no impacts associated with the project constraints.

5.2.2 Alternative B – Improved Upstream Fish Passage at the Winnicut Dam

Alternative B would involve improved upstream fish passage at the Winnicut Dam through the construction of a technical fishpass and decommissioning of the existing fish ladder at the Winnicut Dam. This alternative was developed as a primary alternative because it represents a typical means of mitigating problems associated with fish passage at dams. This alternative is considered feasible and would partially achieve the project goals.

5.2.3 Alternative C – Removal of the Winnicut Dam and Construction of a Technical Fishpass Under the Rte 33 Bridge

Alternative C would involve removal of the Winnicut Dam and the construction of a technical fishpass under the Rte 33 Bridge. This alternative is feasible and presents a means to substantially achieve the project goals.

5.3 SUMMARY OF IMPACTS

Impacts to specific resources in the vicinity of the Winnicut Dam resulting from each of the three primary alternatives were evaluated. The evaluation of impacts to resources included ecological, hydrology, hydraulic and fluvial processes, groundwater, infrastructure, socio-economic, recreational, and cultural and historic factors.

A cost analysis of the primary alternatives is presented in Appendix 7.

A summary of adverse and beneficial impacts to the evaluated resources based on the three primary alternatives is presented in Table 10.

Table 10: Summary of Effects by Level of Intensity

Project Goals		Alternative A		Alternative B		Alternative C	
Goal 1 - Restoration of Fisheries		Does not achieve		Marginal		Substantially achieves	
Goal 2- Restoration of Ecological Continuity		Does not achieve		Marginal benefits		Substantially achieves	
Project Resources		**Impact Intensity**					
Resources Categories	***Resources***	***Adverse Impacts***	***Beneficial Impacts***	***Adverse Impacts***	***Beneficial Impacts***	***Adverse Impacts***	***Beneficial Impacts***
Ecological	*Fisheries*	*Major*	*Negligible*	*Major*	*Major*	*Negligible*	*Major*
	Wetlands	*None*	*None*	*None*	*None*	*Moderate*	*Negligible*
	Wildlife	*Minor*	*None*	*Negligible*	*Major*	*Negligible*	*Major*
Hydrology, Hydraulics, and	*Hydrology and Hydraulics*	*Minor*	*Negligible*	*Minor*	*None*	*Minor*	*Minor*
	Flooding	*Negligible*	*None*	*Negligible*	*None*	*None*	*Minor*
	Sediment Transport	*Minor*	*None*	*Minor*	*None*	*Negligible*	*Minor*
Groundwater	*Groundwater*	*None*	*None*	*None*	*None*	*Minor*	*Negligible*
Infrastructure	*Rte 33 Bridge*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*	*Minor*
	Municipal Use of Impoundment	*None*	*Moderate*	*None*	*Moderate*	*Major*	*Negligible*
	Water Wells	*None*	*None*	*None*	*None*	*Minor*	*Negligible*
	USGS Streamflow Gage	*None*	*None*	*Minor*	*None*	*Minor*	*Moderate*
Socio-Economic	*Socio-Economic Issues*	*Negligible*	*Negligible*	*Negligible*	*Moderate*	*Moderate*	*Major*
Recreational Use	*Fishing*	*Negligible*	*Negligible*	*Negligible*	*Moderate*	*Moderate*	*Major*
	Boating	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Moderate*	*Moderate*
	Other	*None*	*None*	*None*	*Negligible*	*Negligible*	*Negligible*
Cultural and Historical	*Cultural and Historical*	*None*	*None*	*None*	*Negligible*	*None*	*Minor/ Moderate*

Description of Intensity Levels
Negligible: Impacts would not be detectable, measurable, or observable.
Minor: Impacts would be detectable, but not expected to have an overall effect on the resource.
Moderate: Impacts would be clearly detectable and could have short-term, appreciable effects on the resource.
Major: Long-term or permanent, highly noticeable effects on the resource.

6.0 RECOMMENDATIONS

Based on the results of the Feasibility Study, as defined by the ability of the primary alternatives to achieve the project goals within the constraints imposed by the evaluated resources, Alternative C has been selected as the preferred alternative. Alternative C would involve removal of the Winnicut Dam and the construction of a technical fishpass under the Rte 33 Bridge. This alternative is feasible and presents a means to substantially achieve the project goals.

The implementation of Alternative C would provide the maximum benefits relative to achieving the project goals for the restoration of diadromous and resident fisheries and ecological continuity in the Winnicut River ecosystem. While a major adverse impact was assigned to a resource (Municipal Use) in the evaluation of this alternative, this study concludes that this impact is emendable to mitigation. The potential for mitigation of this major adverse impact affords the opportunity for changing the selected level of intensity to moderate. Relative to the other primary alternatives, Alternative C also provides more beneficial impacts associated with the project resources.

Although Alternatives A and B have some lesser impacts associated with project constraints as defined by the resources evaluated in this study, they do not substantially achieve the project goals.

Alternative A, a No Action alternative, would result in no changes to the existing condition or operation of the Winnicut Dam. Alternative A is not considered feasible, as it does not achieve the project goals, results in minor adverse impacts, and provides no beneficial impacts associated with the project resources.

Alternative B would provide for improved upstream fish passage at the Winnicut Dam through the construction of a technical fishpass and decommissioning of the existing fish ladder at the Winnicut Dam. Alternative B is considered feasible and would partially achieve the project goals. However, it would result in major adverse and major beneficial impacts associated with the project resources.

7.0 BIBLIOGRAPHY

GeoInsight, Inc. 1999. Water Resources Evaluation Winnicut River Watershed Study. Prepared for Rockingham Planning Commission, Exeter, NH.

Hughes, P.F. 2002. *A Pleasant and Abiding Place: A History of Greenland, New Hampshire, 1635 – 2000.* Unpublished manuscript on file at the Weeks Library, Greenland, NH.

NHDES (New Hampshire Department of Environmental Services). 1966. Letter in Dam Safety Files. Winnicut River Fishway Reconstruction, Greenland, New Hampshire. F.A. Proj.: New Hampshire F-20-D-1. June 23, 1966.

SRRC (Strafford Rockingham Regional Council). 1981. *Greenland, New Hampshire: Cultural Resources Survey, Inventory, and Plan.* Strafford Rockingham Regional Council Historic Preservation Assistance Project. On file at the New Hampshire Historical Society, Concord, NH.

USACE (US Army Corps of Engineers). 1999. The Highway Methodology Workbook – Wetland Functions and Values, A Descriptive Approach. U.S. Army Corps of Engineers New England District, Publ. NAEEP-360-1-30a.

APPENDICES

Appendix 1 - CULTURAL AND HISTORICAL RESOURCES

A) Project Area Form

B) Phase 1A Archaeological Report (not included, please contact New Hampshire State Historic Preservation Office)

Appendix 2 - WINNICUT DAM TITLE SEARCH

Appendix 3 - WINNICUT DAM INSPECTION REPORT

Appendix 4 - NEW HAMPSHIRE FISHERIES DATA

Appendix 5 - WETLANDS CHARACTERIZATION REPORT AND FUNCTIONAL ASSESSMENT

Appendix 6 - SITE SURVEY

Appendix 7 - HYDRAULICS, FISH PASSAGE, AND COST ESTIMATES

Appendix 8 - FEMA FLOOD DATA

Appendix 9 - SEDIMENT ANALYTICAL DATA

Appendix 10 - CRREL ICE LETTER

Appendix 11 - RTE 33 BRIDGE SCOUR ANALYSIS

Appendix 12 - WELL SURVEY

Appendix 13 - INVASIVE PLANT CONTROL AND BANK STABILIZATION